JUN 22 1934

INSTRUMENTS

THE MAGAZINE OF MEASUREMENT AND CONTROL

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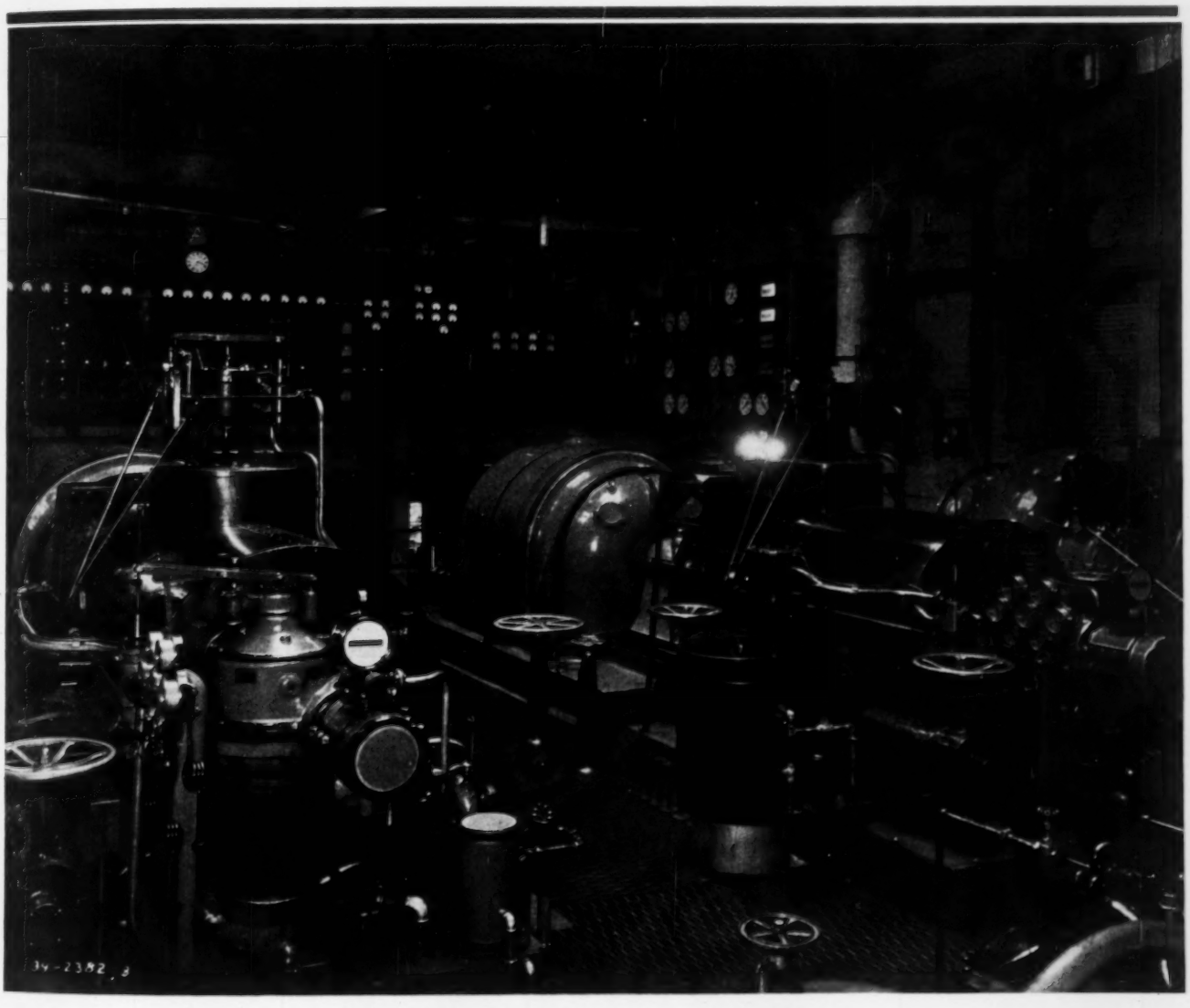

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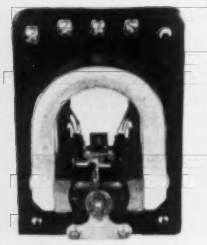
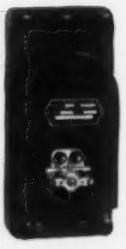
WESTON RELAYS

low energy consuming relays for problems of control . . .

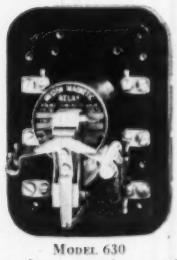


MODEL 704
Sensitive polarized toggle relay for use where operation is required on low energy input. Disconnects itself from control circuit after operation in either direction. Surface mounting.



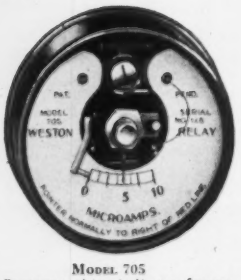
MODEL 30
Highly accurate sensitive relay for point control or galvanometer type of control. Surface mounting.

MODEL 534
Lower cost sensitive relay for point control or galvanometer type of control. Surface mounting.



MODEL 630
A line of power relays made with either mercury or mechanical contacts—multi-circuit—will control circuits up to 3000 watts with less than 1 watt input—may be supplied with interlocking contacts. Surface mounting.

MODEL 613
Thermal time-delay relay of compensated type—single or double circuit—low energy input. Surface mounting.



MODEL 705
Contact making indicator for extreme sensitivity—for signalling or initiating control on minute values. Supplied with indicating scale. Surface mounting.

Weston relays operate from AC or DC current and will function on changes in—

MICROAMPERES
MILLIAMPERES
AMPERES
MILLIVOLTS
VOLTS
TEMPERATURE
FREQUENCY
ETC.

SINCE Weston introduced the first sensitive relay over 30 years ago, many new and useful additions have been made to the Weston line. Sensitive relays, time-delay relays and power relays of various types now are available, making it possible to combine the various circuit functions into a complete control sequence for a wide variety of applications.

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Richard Rimbach

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EDITORIAL COMMENT

In This Issue

Between the lines of this month's first article we discern the implicit promulgation of an audacious concept which in years to come may be hailed as a milestone in the human mind's conquest of the physical universe. **L. A. Trofimov** does not assert it categorically but his article is undoubtedly based on his concept of a "Theory of The Technical Problem and Its Solution." And yet the immediate value of his article is enhanced, rather than diminished, by his discussing only practical examples without expounding the underlying philosophy. His scheme of classification being tentative, your suggestions are invited.

Before becoming Assistant Editor of *Product Engineering*, **R. W. Carson** was for five years instrument and meter development engineer for Westinghouse. It was there that he developed the procedure for making better instrument springs, which he now describes. This procedure was adopted by his company and produced excellent results.

Thanks to **Perry Borden's** long experience, this month's instalment of the electrical measurement series contains not only some litt'e-known practical hints but one or two which were never published before.

In Coming Issues

A discussion of room thermostats and their proper application, with special reference to new developments.

A description of an "almost ridiculously simple" but apparently new method of timing an oscillogram.

A well-illustrated account of automatic sequencing as applied to load control and frequency control of turbo-generators.

Reviews of several new books of special interest to Instrumenticians.

And the articles announced here last month, other than Trofimov's and Carson's.

The Front Cover

A happy man must be F. W. Rabe, Assistant Engineer of the Anheuser Busch Co., in charge of a turbine room where Instrumentation is so far advanced. Without counting the switchboard instruments we can count *twelve* instruments *on* each of the turbo-generators in the foreground. And that's only a part of the story which we hope Mr. Rabe will write up in full.

Instruments in Sports

WHEREVER judges, umpires and referees are called upon by reason of their supposedly keener perceptions to determine quantitative data in sporting events, there are "applications" which cry for instruments where none are used, or for more suitable instruments. Human officials would then decide only qualitative questions, but their role would be more honorable and enviable, we believe, because they would be relieved of functions performable by mechanisms.

Timing furnishes the aptest illustration: the ordinary stop-watch does *not* register the interval of chief interest, but it registers the interval between pressures exerted manually by an observer. Autographic and auto-registering timers have been developed, tried out and found satisfactory. These and other performance-measuring instruments deserve the serious consideration of sports organizations.

Readers who belong to clubs affiliated with national or international sport federations have a chance to put in a good word. They can do more: they can discover new applications and help develop specialized instruments.

In yachting, for example, breakage of masts and rigging could be minimized by applying tension gages to stays. The cable-load indicator of the spring-balance type is a fully-developed instrument well known to the oil industry. It has already been installed on sloop-rigged racing yachts, notably on *Enterprise*, the 1930 America's Cup defender remembered for its duralumin mast and other engineering features. An electrical remote-reading and totalizing stay-load indicator, however, has never been tried out, as far as we can learn. It deserves to be developed and perfected. Not only would it prevent injuries and deaths every season, but it would advance the art.

Just as an airplane pilot uses his instruments with reference to stalling speed and gliding angle to make "happy landings," so will the yacht skipper of the future use a stay-load totalizer and other force-measuring instruments as yet uninvented to make the most efficient use of winds without excessive heel or danger of the mast going overboard. Indeed, we foresee *automatic* control instruments, controlling the mainsheet and other ropes to maintain the forward components of individual sail forces at their most effective values, and lateral and downward components at safe values.

M. F. BEHAR

A REWARD FOR READERS OF THIS PAGE

IN order to set before their readers the balanced diet which these readers want (but seldom write for) publishers and editors must conduct an incessant research into what constitutes the proper diet at any time. The publisher and the editor of this magazine have just emerged with bead-spangled brows from a conference on these matters, at which it was decided to pay for reports. What we want to determine, at this time, is how many subscribers read this editorial page. If you read it as thoroughly as we like, you are reading these lines of small type. Congratulations! You are entitled to a dollar. For obvious reasons we shall not send a dollar in cash to all askers. We will, however, take a dollar off the net price of a book published by this company. "Fundamentals of Instrumentation" is a book which you probably want, whatever your work may be (see ad on page A-4). Its regular price is $2. If you send for it before July 4 and write *Editorial Page* under your signature, you will thereby report yourself as an every-line reader and we shall deduct a dollar from the regular $2 price, and charge only $1. There is no "catch" in this offer: for each report and book order the Instruments Publishing Co. is virtually kissing good-bye to the other dollar represented by the book. (We expect, of course, that this investment in "dietary research" will prove profitable in the long run.) We trust you to make this research cost us exactly what it should, so please do not tip off other subscribers. This reward is for the *subscribers* who read this page thoroughly. Other readers may first become subscribers to the magazine, and then send for the book—all before July 4, 1934. In the case of subscribers who have already bought "Fundamentals of Instrumentation"—well, this is getting complicated but if they report themselves as "every-line" readers we'll find some way of rewarding them.

Filing Technical Ideas

By LEV A. TROFIMOV*

LET us imagine that we have a card file, with divisions A, B, C . . . etc., for indexing articles which profess to present solutions of problems in order to help readers solve their own problems by suggestion or analogy. Let us further assume that we are able to recognize our own problem as belonging to one of the divisions A, B, C . . . etc. Now if we *know* that our problem belongs to division A, for instance, we may look over all the articles listed in that division, thus having an excellent opportunity to find one or more which might suggest a solution to our own particular problem. The desirability of having such a file seems obvious. Benefits to individual engineers and research men, and to industry, may be of paramount importance.

We shall attempt to show here that regardless of certain highly unfavorable conditions, which we shall mention later, such an idea file is an entirely feasible undertaking. By simple analysis we can derive certain general principles necessary for making such a file. I believe, moreover, that by joint effort of those interested in this subject and through the medium of *Instruments* we shall be able to develop all the sufficient and necessary details so that a satisfactory idea file can be made and used.

The chief unfavorable condition for satisfactorily filing magazine articles on an idea basis is the deplorable fact that, although present articles, as they are, profess to be suggestive of ideas, the great majority actually are not. The reason for this is the omission in the articles of the necessary information for making a proper statement of the problem. An article without a statement of the problem involved has no suggestive power of ideas because the reader cannot understand why the solution presented was the preferred solution. Such an article simply amounts to a news item.

I notice with great satisfaction that *Instruments* is apparently particular about having authors include all the necessary information for making a proper statement of the problem. For instance, from A. C. Walker's article on "Recording and Producing Low Humidities" (*Instruments*, Oct. 1933) we can easily make a statement of the problem. The particular problem was —"to make an instrument for recording low humidities by utilizing the known fact that the thermal conductivity of a gas is a function of its molecular weight." Of course there was no such statement in the article. It did, however, contain enough information to make such a statement. The important part of the information given, which is absolutely necessary for any article if it is to be suggestive of ideas, is the mention of the physical principle involved that the thermal conductivity of a gas is a function of its molecular weight—upon which the solution of the problem was based.

As a rule, most articles mention only the need, or the general field in which the problem lies, evidently assuming that this information is sufficient to define the problem. To illustrate what I mean by the term "need" and show that it is irrelevant for defining a problem, I am quoting the first paragraph of the Walker article which specifies the need: "One of the recent improvements in the manufacture and handling of lead-covered telephone cable is the storage of the dried cable cores in ovens whose atmospheres are as free as possible from water vapor. The control of these ovens requires the use of apparatus for continuously measuring and recording the low humidities."

If Mr. Walker had omitted the next two paragraphs, his article would still remain readable, but it would lose its suggestive value because it would be impossible to make a statement of the problem from the remaining information, and the reader would never guess why "the fine platinum wire and the Wheatstone bridge" are necessary for solution. This is exactly the way most technical articles are written. With shorter articles the situation is still worse. I believe that it is entirely possible and imperative, in any and every case which professes to be suggestive of ideas, to write an article without increasing its length in such a way that the reader will be able to make a statement of the problem and to understand why the solution was such as it was.

Fortunately, not all technical articles are written without thought of stating the problem. A few good ones appear which make readers want to file them in some orderly way. In constructing the following system of classification of problems, my chief purpose was to obtain the greatest possible amount of practical utility. I am fully aware of its imperfection but it is the first one, out of several, which I actually am able to use, and with remarkable profit.

*Development Engineer, The Electric Controller & Mfg. Co.

FIRST—FORCE OR SUBSTANCE

Although all the problems always deal with both substances and forces, in each particular problem either force or substance definitely predominates. For instance, although in the problem which led to the development of Miller's continuous viscometer for oils (*Instruments*, Jan. 1933) both the substance (oil) and the forces of internal friction (viscosity) were prominently involved, viscosity or molecular force was definitely of major importance. Therefore we are led to recognize this problem as a "force problem." In the development of the low humidity recorder the developer was chiefly concerned with an amount of the vapor in air or, speaking generally, with a substance, hence we recognize the second type of problem—"substance problem." This distinction suggests an arrangement of all problems into two great classes: Class F (force) and Class S (substance). Quite logically we are led to sub-divide each of these great classes into smaller groups according to the kinds of forces and states of substances.

KINDS OF FORCES

Thus, problems dealing with mechanical forces will be designated by F. K. (the K standing for both kinetic or kinematic); those with gravitational forces by F. G.; those with electromagnetic (including electrostatic) forces by F. Em.; those with molecular forces by F. M. (Miller's Viscometer belongs here); and those with electronic forces by F. Eo.

STATES OF SUBSTANCES

Problems dealing with the various states of substances will be divided into three classes: solids, liquids and gases, designated by S.S., S.L., and S.G. respectively. Thus we already have eight different types of problems.

PREVAILING CONDITIONS

Further division of problems may be made according to the predominant conditions imposed by the problems. I have chosen five such conditions: (1) small scale condition; (2) large scale condition; (3) avoidable interfering condition; (4) unavoidable interfering condition; and (5) condition of order. (I make no particular claims for the correctness or complete adequacy of this list of the chosen conditions.)

Small scale condition. There are problems, the chief difficulty of which is their minuteness of scale. They are often typified by the necessity of using principles of amplification and balancing (*e.g.* Wheatstone bridge in the low humidity recorder).

Large scale condition. An example of this type of problem was the construction of the doors for the Akron hangar at the Goodyear Air Dock in Akron, Ohio. It *is* a problem to make a door 202 feet high, 214 feet wide and weighing 600 tons. Large and small scale problems, however, are determined not only by actual size but also by radical deviation from the ordinary practice. Moreover, the term "scale" involves not only linear or cubic dimensions in particular but in general all magnitudes such as: number, time, temperature, etc.

Avoidable interfering condition. In the development of precision regulators for high pressure gases by George M. Deming (*Instruments*, Sept. 1933), there was the problem of preventing variation in friction of the seat-carrying means of the regulator due to the accidentally additive or subtractive action of the compensating and adjusting helical springs, caused by the lateral distortion of these springs. The solution was obtained by the substitution of a specially shaped flat spring for the helical compensating spring, and also by making the adjusting helical spring shorter. This simply illustrates the way in which the disturbing condition was permanently removed, and goes to show that this condition was not a necessary element of problem or solution (as will be clear after reading the next paragraph).

Unavoidable interfering condition. We quote from Deming's article: "An ideal regulator would be one which maintains a low delivery pressure notwithstanding a deterioration of cylinder pressure from an initial value of more than 2000 lbs./in.²

CLASS OF PROBLEM	F																			
KIND OF FORCE	K					G					Em					M					Eo				
PREVAILING CONDITIONS	S	T	A	U	O	S	T	A	U	O	S	L	A	U	O	S	L	A	U	O	S	L	A	U	O
ASSOCIATIVE ELEMENTS	Ql	Ql	Ql	Ql	Ql	Ql	Ql	Ql	Ql	Ql	Ql	Ql	Ql	Ql	Ql	Ql	Ql	Ql	Ql	Ql	Ql	Ql	Ql	Ql	Ql
	Qn	Qn	Qn	Qn	Qn	Qn	Qn	Qn	Qn	Qn	Qn	Qn	Qn	Qn	Qn	Qn	Qn	Qn	Qn	Qn	Qn	Qn	Qn	Qn	Qn
	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C

CLASS OF PROBLEM	S														
STATES OF SUBSTANCES	So					Li					Ga				
PREVAILING CONDITIONS	S	L	A	U	O	S	L	A	U	O	S	L	A	U	O
ASSOCIATIVE ELEMENTS	Ql	Ql	Ql	Ql	Ql	Ql	Ql	Ql	Ql	Ql	Ql	Ql	Ql	Ql	Ql
	Qn	Qn	Qn	Qn	Qn	Qn	Qn	Qn	Qn	Qn	Qn	Qn	Qn	Qn	Qn
	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C

LEGEND

Classes of problems: F—force; S—substance.

Kinds of force: K—mechanical; G—gravitational; Em—electromagnetic; M—molecular; Eo—electronic.

States of substance: So—solid; Li—liquid; Ga—gas.

Prevailing conditions: S—small scale; L—large scale; A—avoidable interfering condition; U—unavoidable interfering condition; O—ordinal.

Associative elements: Ql—quality; Qn—quantity; T—time; S—space; C—consciousness.

to an end value of less than 20 lbs./in.^{2} . . . The equilibrium of forces controlling the position of the valve seat . . ." is disturbed by the fall of cylinder pressure "with the result that the delivery pressure of the regulator is adversely affected." In this case the source of trouble is the fall of cylinder pressure, which is unavoidable and is a necessary element of the problem.

A condition of order. The fifth condition demands a solution containing an orderly feature with respect to time, space or consciousness. All problems of indication, measurement and control belong to this sub-class.

ASSOCIATIVE ELEMENTS

So far, we have three successive ways of distinguishing the problem: (1) the nature of the element we deal with—force or substance; (2) the kind of force or state of substance; and (3) the predominating condition which actually makes the problem. This has given us forty sub-classes, but I feel the necessity of including one more break-down; this time according to the psychological element which might be responsible for an idea of solution. It is hoped that the mention of this element will in turn stimulate the imagination of the reader and point to a probable solution of his own problem. These associative elements are words: (1) quality, (2) quantity, (3) time, (4) space and (5) consciousness; abbreviated as Ql, Qn, T, S and C; their use will be illustrated below.

EXAMPLES

In order to show how the whole system of classification may work, we shall classify several problems from Deming's article, which is an excellent presentation as well as a fine job of writing, and therefore can be easily used for our purpose.

PROBLEM No. 1

Statement: To reduce or eliminate the fall of the delivery pressure with the deterioration of cylinder pressure (regulator inlet pressure). *Solution:* The two stage pressure regulator; (*a*) mechanism for the first stage of pressure reduction *primarily suitable for high pressure regulation;* and (*b*) a second stage of pressure regulation *primarily suitable for low pressure regulation.* The filing letter combination will be F—M—U—Ql. We deal here with the molecular forces of gas, hence M. The deterioration of cylinder pressure is an unavoidable condition, hence U. The solution was obtained by a careful design of each stage of reduction, perfecting it to perform its particular function, hence Ql (quality). This word "quality" may also suggest to the reader to attempt to solve his problem by a quality design.

PROBLEM No. 2

Statement: To prevent the variation in friction of the seat-carrying means of the regulator, due to the accidentally additive or subtractive action of the compensating and adjusting helical springs caused by the lateral distortion inherent in long helical springs. *Solution:* Substituting the crescent-shaped stamping of spring steel for the helical compensating spring and making the adjusting spring shorter. The filing letter combination will be S—So—A—S. We deal here with solid parts or substances, hence S—So. The predominant condition is the accidental misalignment of parts, hence A (avoidable). And the solution was finally obtained by the radical change in the shape of springs, hence S (space includes shape). This word "space" may suggest trying to solve a similar problem by some change in shape.

PROBLEM No. 3

Statement: To prevent, in the seat-carrying means of the pressure regulator, excessive loose play due to ordinary machining and assembly manufacturing tolerances. *Solution:* Seat accommodation is provided by permitting the seat to rock. Positive seat alignment is secured through the particular design of the lever (ball in a conical cavity held by a spring). The filing combination will be S—So—U—Ql. We deal here with solid parts, hence S—So. The loose play due to manufacturing tolerances is unavoidable, hence U. The solution was obtained by radically changing the design of the seat mounting and the seat carrying means, hence Ql.

PROBLEM No. 4

Statement: To prevent excessive temperature rise at the seat surface, due to sudden inrush of high pressure gas being momentarily stopped at the seat. *Solution:* Dead-end pocket beyond the regulator seat was provided so that the stoppage of the inrush gas had to take place in this pocket instead of at the seat. The combination will be F—M—A—S. We deal here with the molecular forces of a gas, hence F—M. The excessive rise of temperature whenever the intake valve was open is an unavoidable condition; but that this temperature rise should always take place at the surface of the seat is not unavoidable, hence A. The solution was obtained by shifting the location of trouble away from the seat into a specially provided dead-end pocket, hence S (change in space).

PROBLEM No. 5

Statement: To provide an indicator to show whenever a relief valve was caused to operate. *Solution:* A red bordered signal button was provided, which would be forced out by the first stage diaphragm in the event of any pressure appreciably higher than normal occurring. The filing combination will be

F—K—O—C. Here we deal with motion of mechanical parts, hence K. The requirement was to indicate somehow whether the relief valve had operated or not, hence O (condition of order, includes indicating problems, as well as measurement and control). The solution was of visual nature, hence C (consciousness).

CONCLUSION

There is only one way of finding out whether this system of classification of problems for filing purposes is of practical importance or not, and that is by trying to put it to use.

If this, or a similar system, proves to be of practical utility, one can readily visualize the tremendous importance of such a file as it grows and grows without ever becoming a graveyard. As it is now, there is no practical way of profiting by suggestive articles written two months or more ago. Present kind of indexes for magazine articles generally refer to needs and not to the nature of problems. Therefore, the publishers of technical magazines, it seems to me, must be keenly interested in the development of some kind of index of ideas, because it will prolong the life of all their issues indefinitely.

NEWS AND NOTICES

Alfred V. deForest, widely known research engineer, who is a member of the Editorial Advisory Board of *Instruments*, has been appointed associate professor of mechanical engineering at the Massachusetts Institute of Technology. In the autumn he will join the staff at Technology where his special field will include study of dynamic properties of metals, particularly the strength of full-size parts, and the relations among design, metallurgy, and application of load in modern machinery. The forces which produce and the factors that limit resonant vibrations will be investigated by Mr. deForest, who will give special attention to the development of new test methods and measuring instruments. His work is expected to lead to the establishment of a laboratory in which the knowledge and experience of the machine designer, the metallurgist and the physicist can be focussed on the working properties of machine materials.

Mr. deForest was educated at the Middlesex School of Concord, Mass., and at M.I.T., where he was graduated in 1912. He was employed by the New London Ship and Engine Co. for a year, then taught engineering at Princeton until 1915. At the same time he began special studies in metallography under Donald P. Smith of Princeton and William Campbell of Columbia. From 1916 to 1918 he was associate research engineer of the Union Metallic Cartridge Co., and from 1918 to 1928 research engineer of the American Chain Co. Since then he has been a consulting engineer specializing in the invention and application of various special test and inspection methods. He has published a number of technical papers on magnetic methods of testing, one of them winning for him the A.S.T.M. Dudley medal in 1928. Since 1924 he has been secretary of the society's committee on magnetic analysis. He improved the magnetic continuity test invented by W. E. Hoke, which is valuable in the study and prevention of metal fatigue failures, particularly in the airplane field. He developed several test methods for fatigue of metals, and his work on inelastic behavior of metals has resulted in a new type of spring used in testing machines (*Instruments*, March 1934, page 61) and in precision scales (page 119 of this issue).

Douglas Annin, who has developed a number of control patents pertaining to valves and automatic regulators, has joined the Industrial Regulator division of Minneapolis-Honeywell Regulator Co., which is in charge of Ralph L. Goetzenberger. Mr. Annin was chief engineer of Neilan Company, Ltd., Los Angeles, and when this firm was merged with the Mason Regulator Co., he became Sales Engineer of Mason-Neilan.

The Trustees of Battelle Memorial Institute, Columbus, Ohio, announce the appointment of **Clyde E. Williams** as Director of the Institute, and **Dr. H. W. Gillett** as chief technical adviser, in line with an expansion program. A greater range of research and development work within the Institute has been planned, and many new projects of outside sponsorship have been accepted. Both Dr. Gillett and Mr. Williams have been associated with the Institute since 1929, Dr. Gillett as director, sharing the administrative duties of the directorship with Mr. Williams as associate director, and at the same time serving as metallurgical supervisor of the Institute. Dr. Gillett will now devote his entire time to the scientific side of the work. He will head a group of engineers who will bring to sponsored projects the highest type of scientific knowledge in the Institute's chosen fields.

The twentieth anniversary of the Canadian unit of Taylor Instrument Companies has just been celebrated. **H. A. Allen**, who in 1914 was appointed representative of the Rochester firm, heads the Canadian corporation which now occupies its own factory and office building in Toronto.

The **Amthor Testing Instrument Co.**, manufacturers of speed recorders and testing instruments for paper, cordage and light metals, has moved from 309 Johnson St. to 4-10 Leo Place, Brooklyn. The new plant combines office, showroom and factory on one floor and provides more complete facilities for handling increasing business.

Reorganized with increased manufacturing and field facilities, the Isometer Co., Elgin, Ill., manufacturers of flow meters, is now housed in a new factory and office at 397 Silver Street, and is now known as the **Isometer Corporation.** Officers of the new organization are E. F. Eckel, Pres.; V. W. Eckel, Sec'y; F. Ralph Fisher, Treas.

The **W. M. Chace Valve Company** has started construction of a new addition to the present quarters. Located on Beard Avenue, Detroit, the plant, when addition is completed, will have more than 19,000 square feet of floor space. The new quarters will be almost entirely utilized by the Thermostatic Bimetal division of the business.

The Foxboro Company, Foxboro, Mass., has become a member of the American Standards Association.

The Semi-Annual Meeting of the American Society of Heating and Ventilating Engineers will be held at The Inn, Buck Hill Falls, Pa., June 19-22. Among the papers are: "Criteria for Industrial Exhaust Systems" by J. J. Bloomfield; "Dry-bulb *vs.* Effective Temperature Control" by A. E. Beals; "Operating Results of an Air Conditioning System Compared with Design Figures" by J. R. Hertzler; "Insulating Value of Bright Metallic Surfaces" by Prof. F. B. Rowley; "Heat Transfer from Direct and Extended Surfaces with Forced Air Circulation" by Prof. G. L. Tuve and C. A. McKeeman.

Textile Microscopy, textile technical analysis, and textile laboratory are the special summer courses being offered again this year by the Massachusetts Institute of Technology under the direction of E. R. Schwarz. The work begins on July 25 and continues for six weeks, ending on September 5. Registration for the laboratory work is limited and early application is necessary. Excellent living facilities are available at moderate cost in the new dormitory group.

Six- to eight-week courses in microchemistry are offered during the summer session of 1934, starting June 7, by the Department of Chemistry, Washington Square College, New York University, under the direction of J. B. Niederl, A. Benedetti-Pichler, and B. Alber. Address inquiries to W. C. MacTavish, Washington Square College, New York University, New York, N. Y.

St. John X-Ray Service, Inc., 30-20 Thomson Ave., Long Island City, N. Y., will give a course in industrial radiography beginning July 2 and extending for four days, but with no sessions on July 4. While previous metallurgical training is desirable, it is not required, and any high school graduate will be able to understand the course. The $100 fee includes the use of equipment and materials.

A new form of service, which keeps the manufacturer advised month by month of new inventions in his field, is announced by **Inventions Digest, Inc.**, Chicago. This organization is not affiliated with any patent attorney. It simply collects descriptions of recent inventions from patent attorneys all over the country, and sends monthly reports. Subsequent negotiations for sale or licensing are handled directly between the manufacturer and the inventor's attorney. "Inventions Digest, Inc. does not and will not undertake any promotions."

Hooke's Law Amended

Aging and Lag Effects in Instrument Springs

By R. W. CARSON*

INTRODUCTION

AT the time he published his *Lectures on Springs*, 260 years ago, Robert Hooke little realized that there were so many qualifications to his statement, *ut tensio sic vis*, "as the deformation so the force." Unfortunately, the ideal elasticity of the physicist does not exist for the designer. The problems of non-proportionality and imperfect elasticity become more pressing as increasing sensitivity and greater accuracy are demanded in such devices as modern electrical instruments, gages, weighing devices and other spring controlled mechanisms.

According to the usual conception, in the ideal elastic material the deflection under load is directly proportional to the intensity of the load, but, unfortunately, perfect elasticity fulfilling the ordinary interpretation of Hooke's Law is unobtainable in materials suitable for sensitive elastic elements. In the first place, the deflection is not exactly proportional to stress. A curve published nearly 30 years ago by Bradshaw[1] shows that springs in precision electrical instruments have a non-uniform deflection rate.

Although a perfectly elastic material need not have a straight-line relationship between stress and deflection, steel closely approaches this relationship, and for this reason all materials are assumed to give a straight-line diagram. For most engineering materials and most applications the assumption of a straight-line relationship or a constant elastic modulus is close enough, but for elastic elements of modern precision instruments this assumption does not hold.

As shown by Sayre[2], the true tension modulus for the usual spring material is given by the following equation in which E is the projected elastic modulus for zero stress and S is the stress:

$$\text{True Modulus} = E - K S$$

The constant K has values between 4.3 and 10.9 for different metals, and depends also on the condition of the material, on the heat treatment and on the method of fabrication.

From Sayre's relation it is apparent that the deflection rate or elastic modulus increases with the load or stress, so that the stress-strain curve is a curve in reality, and no true proportional limit exists. To be sure, the variation in elastic modulus, as given in Table I, is usually $< 1\%$ for materials and working stresses ordinarily used for elastic elements; but it must be recognized that in the use of precise elastic members, where "one per cent variation" is intolerable, Hooke's Law is only a rough approximation and the term "proportional limit" has no meaning. Experience in instrument design teaches that working stresses for the elastic elements must be much lower than for structural or load supporting parts. Otherwise, the performance of the instrument will be impaired by one or more of three effects: *fatigue*, *aging* and *lag*. "Fatigue" or failure caused by repeated stresses is already well covered in the literature, an excellent discussion by Gillett[3] appearing in a previous number of *Instruments*; the other two effects have been discussed by Behar[4] in respect to their effect on instrument performance, but there has been no discussion of these inelastic properties of materials from the designer's point of view.

TABLE I—MODULUS OF ELASTICITY IN TENSION

Material	Diameter	Modulus
Hard copper wire	0.051 in.	19,120,000 — 6.0 S
Phosphor bronze wire	0.040 in.	15,580,000 — 5.4 S
Spring temper phosphor bronze, $\frac{1}{8} \times \frac{1}{2}$ in.		14,700,000 — 10.8 S
Spring temper brass wire as drawn	0.040 in.	14,300,000 — 4.6 S
17ST aluminum alloy wire	0.065 in.	10,290,000 — 10.9 S
0.67% C heat-treated steel wire	0.0281 in.	30,910,000 — 6.6 S
1% C heat-treated steel	0.0327 in.	29,040,000 — 5.0 S
Hard drawn spring wire	0.043 in.	28,920,000 — 6.8 S
Music wire	0.025 in.	29,920,000 — 4.8 S
$3\frac{1}{2}$% nickel steel	0.500 in.	29,190,000 — 4.3 S
Heat-treated silicon steel	0.328 in.	29,120,000 — 6.7 S

CHARACTERISTICS OF AGING AND LAG

Aging and lag are distinguished from fatigue in that they are irregularities in the deflection rate or elastic modulus of the spring members. Aging is a slow permanent change in elastic properties and physical condition of the spring element, influenced to a great extent by temperature but independent of the load or working stress. Spring lag is evidence of the inability of the spring material to respond in the same manner to decreasing stress as to increasing stress, or more specifically is a lag of the strain in relation to the stress. The most pronounced lag is influenced by time, the effect increasing with time.

Present-day engineering knowledge leads to the belief that both aging and lag

[1]

Potentia Reſtitutiva,

OR

SPRING.

THe Theory of Springs, though attempted by divers eminent Mathematicians of this Age has hitherto not been Publiſhed by any. It it now about eighteen years ſince I firſt found it out, but deſigning to apply it to ſome particular uſe, I omitted the publiſhing thereof.

About three years ſince His Majeſty was pleaſed to ſee the Experiment that made out this Theory tried at *White-Hall*, as alſo my Spring Watch.

About two years ſince I printed this Theory in an Anagram at the end of my Book of the Deſcriptions of Helioſcopes, *viz. ceiiinosssttuu, id eſt, Ut tenſio ſic vis*; That is, The Power of any Spring is in the ſame proportion with the Tenſion thereof: That is, if one power ſtretch or bend it one ſpace, two will bend it two, and three will bend it three, and ſo forward. Now as the Theory is very ſhort, ſo the way of trying it is very eaſie.

Take then a quantity of even-drawn Wire, either Steel, Iron, or Braſs, and coyl it on an even Cylinder into a Helix of what length or number of turns you pleaſe, then turn the ends of the Wire into Loops, by one of which ſuſpend this coyl upon a nail, and by the other ſuſtain the weight that you would have to extend it, and hanging on ſeveral Weights obſerve exactly to what length each of the weights do extend it beyond the length that its own weight doth ſtretch it to, and you ſhall find that if

B one

Fig. 1. First page of pamphlet (1678) in which Hooke published his law. Original in library of Professor M. F. Sayre. Plates from The Davis Press, Worcester, Mass., through courtesy of The Wallace Barnes Co., Bristol, Conn.

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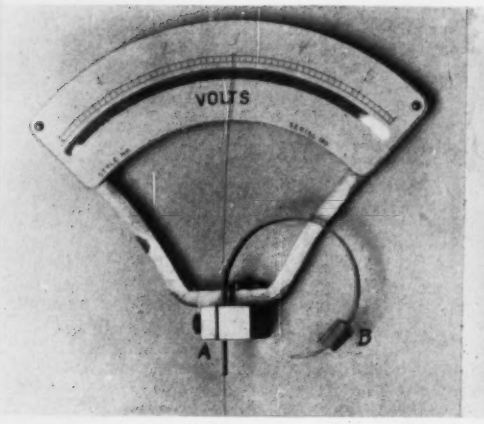

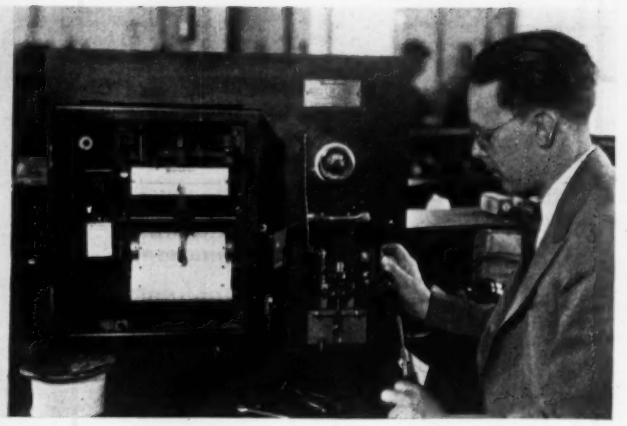

THE SIMPLEST AND THE MOST ELABORATE INSTRUMENTS FOR ACCURATELY DETERMINING PROPERTIES OF RIBBON-FORM SPRING MATERIALS

Fig.2. A simple apparatus like this can provide reliable data on elastic properties of different materials. Clamp ribbon at A. Note original position of ribbon on scale. Bend it around curved form and clamp it at B. Let stand for given time at given temperature. Observe behavior after release.

Fig. 3. The author with his recording electronic micrometer used in obtaining accurate measurements of elastic lag in spring ribbon by automatically plotting the changes in deflection of a spring ribbon under a steady load. Employing a gear-driven hand micrometer and a gaseous rectifier tube to detect contact with the ribbon, the primary device (center) is sensitive to a ten-millionth of an inch.

are closely related and arise from comparatively simple causes, but much mystery surrounded these two effects in the past. Many "secret" processes were originated for the purposes of controlling aging and lag, and many "secret" formulas for spring or diaphragm materials have been developed by rule-of-thumb processes.

Although the use of these secret materials and processes in combination with careful testing and selection of finished spring elements has resulted in a marked improvement in certain types of instruments, aging and lag are inherent properties of *all* manufactured elastic elements. They cannot be eliminated by any mystic, ritualistic shop processes. Only when the factors that influence aging and lag are known can they be brought under control.

TERMINOLOGY

Information on elastic defects of the various materials used by instrument designers is incomplete, widely scattered, and difficult to correlate because of the lack of uniformity in the terms used: No two investigators have been able to agree on the nomenclature. The following list of terms used by different investigators, or in use in specifications, or in current shop use, is by no means complete but will serve to indicate the difficulty in correlating data from different sources. Included with this partial list of terms is the particular meaning associated with each:

Drift (change in altimeter diaphragms with time; in general, any long-time change of calibration).
Secular error (drift in altimeters).
Aging (changes taking place unaffected by load).
Creep (increase in elongation at constant load in a tensile test specimen).
Recovery (decrease in length after removal of load from a creep test specimen).
After-effect (residual strain after unloading a tensile specimen).
Elastic-afterworking (literal translation of the German *elastischen-achwerkung*).
Zero shift (shop term indicating failure of instrument pointer to return to zero).
Temporary shift (zero shift that disappears in time).
Permanent Set (zero shift that does not disappear within a few hours).
Fatigue (sometimes used inaccurately for any inelastic effect).
Elastic hysteresis (difference between strain for equal ascending and descending loads).
Back error (shop term used to denote total hysteresis in scales, which of course includes friction).
Cyclical hysteresis (elastic hysteresis after a number of repeated loadings).
Statical hysteresis (term used by Bureau of Standards for elastic hysteresis of a specimen in cyclic state).
Hereditary hysteresis (elastic hysteresis influenced by previous history).
Internal friction (cause of decrement measured in torsional pendulum tests).
Dynamic ductility (cause of damping of torsional vibrations).
Mechanical hysteresis (in tensile or bending tests is the same as elastic hysteresis).
Elastic fatigue (inaccurate expression for any inelastic effect).
Viscosity (used by British writers for internal friction).
Visco-elasticity (another British term for internal friction).

This is truly an imposing list of terms for two comparatively simple elastic defects. Further confusion is added by the fact that different groups of these terms are used synonymously by some engineers and physicists while other workers apply the terms at times without regard to the character of the effect.

AGING INDEPENDENT OF LOAD

Aging, the slow permanent change that takes place regardless of the load, is the effect known as "secular error" or "seasoning" in altimeter diaphragms. The terms drift, permanent set and zero shift are applied to aging effects in springs, particularly to the spiral springs in instruments and gages. As reported from various sources aging changes are most active shortly after manufacturing processes are completed, causing permanent changes in elastic modulus, hardness, ductility, physical dimensions and structure. These changes in shape are invariably in such a direction as to relieve deformations introduced in manufacturing. As early as 1898 Chree[5] reported that "secular error" or aging tendency in aneroid barometers decreased with time. Aging in spiral instrument springs is referred to as early as 1915 in a Bureau of Standards discussion of the sources of error in electrical instruments.[6] According to this authority: "Another form of zero-shift is caused by the gradual change in form of springs with time. This has been observed in a number of instruments using a single spiral spring, and the change observed was evidently a gradual uncoiling of the spring."

Again emphasizing the effect of time, speedometer springs are reported to have consistently increased in stiffness in parallel with this uncoiling tendency, within a period of two years. This effect has been described in discussions included with two contributions to the American Society of Mechanical Engineers.[7, 8]

Several physicists, in using a torsional pendulum in connection with investigations of inelastic effects, have reported changes in elastic modulus with only the passage of time. The earliest reference to such an effect was published in 1865 by Lord Kelvin.[9] Since that time Iokibe and Sakai, Honda and Konno, Subrahmaniam, and others have in every instance reported aging effects in various spring materials.

Uncoiling in spiral instrument springs is shown to be closely related to changes in stiffness of the spring in a recent paper by the writer.[10] In fact these two effects are shown to be parallel, and the conclusion is drawn that "The tendency of the spiral spring to uncoil and increase in elastic modulus is a minimum under conditions that produce minimum residual stresses."

INTERNAL STRESSES CAUSE AGING

Aging effects are not limited to instrument springs and diaphragms. Recently, an enlarged interest in this problem has brought forth a number of parallel effects. In cold working of cannon, in cold rolled steel sheets, in locomotive tires, in quenched steel castings, in iron castings, in zinc die castings and other products, aging effects have been measured and reported. In the aging of permanent magnets—another problem in the design of many electrical measuring instruments and in the season cracking of cold drawn brass there are similar effects. In the changes in the physical properties of cold worked lead and zinc at normal temperatures, in copper at slightly elevated temperatures, in tin, in the precipitation hardening of copper and aluminum alloys, in steels at elevated temperatures, in fact in any cold worked material, physical properties are altered by aging.

In nearly all of the reported investigations three facts are invariably recorded. First, aging is noted immediately after subjecting the material to mechanical working, or following a heat treatment that leaves the material in an un-annealed or unstable state. Second, aging proceeds at a decreasing rate, reaching a stable state only after an extended period of time. Third, these aging changes are accelerated by small increases in temperature.

These phenomena suggest that aging is a direct result of internal stresses introduced in the material during the mechanical working or heat treatment, and that elimination of aging, then, requires only the elimination of the internal stresses. The aging changes, proceeding in proportion to the intensity of these internal stresses, will decrease in rate as the internal stresses are relieved by aging. But this action can be speeded up and the unstable condition normalized much quicker by heating the material so as to accelerate the relief of these internal stresses. For phosphor bronze instrument springs complete relief of internal stresses may be obtained in 20 hours at 100° C. (212° F.) while at 40° C. (104° F.) more than 20,000 hours (two years) would be necessary.

Although heat treating time will be shortened by using higher temperatures, the temperature selected should not be so high as to cause annealing. In fact, heat treating temperatures need be only slightly greater than the maximum service temperature the spring element will meet. Table II[11] gives the

TABLE II—HEAT TREATMENT TO REDUCE INTERNAL STRESSES

Spring Material	Heat Treatment
Phosphor Bronze	100° C. for 15 hr.
Hard Drawn Brass	120° C. for 10 hr.
Hard Drawn Nickel Nickel Silver Monel Metal	150° C. for 8 hr.
Low Carbon Steel Low Alloy Steel	200° C. for 5 hr.
Music Wire High Carbon Steel Nickel Steel	300° C. for 5 hr.

maximum aging temperatures recommended for various spring materials along with the number of hours at temperature to stabilize the usual spring members. If the material is subjected to an unusual amount of cold forming or lower temperatures are used more time may be needed. For bronze, brass, nickel silver and Monel metal the heat treating temperatures given in the table are low enough so that the elastic elements can be heated after assembly in most instances. This procedure is strongly recommended as the spring elements may be so handled during assembly that new aging effects are introduced, even though the parts were previously stabilized.

In the above discussion the term "aging" is used in reference to the phenomena that supposedly result chiefly from internal stress and not in reference to the phenomenon of precipitation hardening which, also—largely because it occurs in duralumin with time at room temperature—is commonly called aging. Precipitation hardening effects occur in the alloys used for spring materials only at temperatures much above those recommended in the table.

One of these age-hardening spring materials, beryllium copper, has recently demanded attention because of its high strength and corrosion-resistance but no data are available on its inelastic properties.

LOAD AND TIME INFLUENCE ELASTIC LAG

The third inelastic effect, lag, is observable as a deviation between deflections produced by ascending and descending loads. General terms applied to this effect include creep, elastic hysteresis, recovery, after-effect, zero shift, temporary set, elastic lag, elastic fatigue and elastic after-working. For certain types of lag specialized terms such as statical hysteresis, dynamic ductility, damping capacity, visco-elasticity, internal friction, mechanical hysteresis and hereditary hysteresis have been used by various investigators.

Much confusion in the compounding of these descriptive terms has been caused by the fact that many of the earlier investigators did not realize that they were dealing only with different manifestations of the same effect. In fact, it is recognized now that there are only two types of lag, one nearly independent of time which appears to be something on the order of elastic "back-lash," while the second type of lag is a slow continuing deflection taking place under a steady load, the action entirely dependent on time.

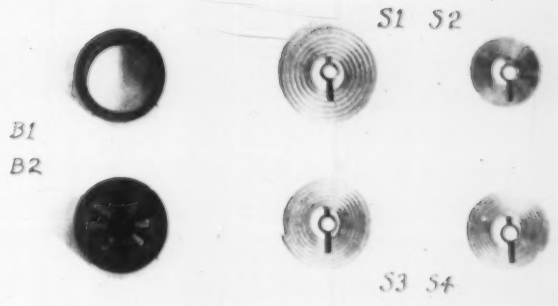

Fig. 4. UNWINDING OF INSTRUMENT SPRINGS—BENEFICIAL EFFECTS OF PROPER HEAT TREATMENT. (Slightly less than actual size.)

B-1. Instrument spring forming barrel used in making special springs. Inside diameter 0.436".

B-2. Forming barrel wound with six ribbons ready for forming. Ribbons are 9.5" long, 0.023" wide and 0.0022" thick.

Springs made from identical ribbons, formed in above barrel in air oven at different temperatures and for different durations.

S-1. Formed for 15 min. at 250°C. Outside diam. 0.633" (45% expansion).

S-2. Formed for 15 min. at 320°C. Outside diam. 0.461" (6% expansion).

S-3. Formed for 4 min. at 300°C. Outside diam. 0.578" (32% expansion).

S-4. Formed for 30 min. at 300°C. Outside diam. 0.500" (15% expansion).

Both aging tendency and elastic lag are more pronounced in springs that expand relatively more when removed from forming barrel after heat treatment.

Three investigations of the back-lash type of lag are outstanding. Keulegan[12] clearly distinguishes between the two types of lag designating the effects "statical hysteresis" and "hereditary hysteresis." In a later paper[13] Keulegan reports a series of accurate measurements of the statical or back-lash type. In another investigation conducted by Kimball and Lovell[14] measurements of lag were obtained by the novel method of measuring the small horizontal displacement of a free and rapidly rotating horizontal shaft loaded as a cantilever beam. This report includes a table of coefficients for the lag in various materials, using the term internal friction.

ELASTIC LAG CAUSES DECAY OF TORSIONAL VIBRATIONS

More recently, a report by Von Heydekampf[15] describes lag measurements based on the decrement or decrease in amplitude of torsional vibrations in specimens of various materials. Curves of lag coefficients for several spring materials at various loads are given using the terms "damping capacity" and "dynamic ductility." The author successfully correlates his results with those of Kimball and Lovell and others.

These three investigations of the back-lash type of lag provide data that are fairly consistent over a wide range of load stresses for most of the ordinary spring materials. Duration of load or speed of loading is shown to have little effect, but the amount of lag increases rapidly as the load stress is increased. In general it is shown that doubling the stress increases the lag to about three times the initial amount. However, for load stresses this effect is comparatively small, being no more than approximately 0.25% of the load strain for the usual spring materials. The effect appears to be a property of the molecular structure of the material, and is unaffected by mechanical working or heat treatment.

Of much greater importance in spring design is the type of lag that varies with time. This effect causes comparatively large changes that may vary continuously even when all other conditions are unchanged. Also, the magnitude of this time lag depends on the physical state or previous history of the part—conditions which are often unknown and always difficult to control in manufacturing processes.

This time lag was studied as early as 1865 by Lord Kelvin and reported[9] in that year, describing "viscosity" effects noted in the suspension for a long-period torsional pendulum. A number of other investigators have since reported similar effects, including Sayre in his series of reports to the A.S.M.E. Special Research Committee on Mechanical Springs.

MEASUREMENTS OF TIME LAG

Time lag in altimeter diaphragms was recognized a number of years ago and reported by Stewart[16] in 1869. More recent measurements are included in reports of the National Advisory Committee for Aeronautics. Hersey[17] studied the increase in deflection with constant load and the corresponding after-effect when the load was removed. Brombacher[18] and Beij[19] both discuss these time lag problems in altimeters.

Measurements of time lag in large helical springs of phosphor bronze were made and reported by Brombacher.[8] The author's recent paper[10] also presents measurements of time lag in bronze spring ribbon loaded in bending. The data were obtained by measuring deflection changes in a small beam loaded with a weight using a highly sensitive electronic recording instrument, Fig. 3. As shown in this paper, the lag under a load proceeds at a constantly decreasing rate that is shown to be logarithmic—the rate, too, varying approximately as the square of load stress. The reverse lag occurring when the load is removed proceeds at a much slower rate than lag under load. Curves given in this paper for a typical test show that under load ¼ of the total lag measured in 24 hours took place during the first hour, while during the first 24 hours after removing the load only 2/3 of the return lag occurred.

One important fact disclosed in this paper is that the factors affecting time lag are the same as those controlling aging, internal stresses being responsible for both effects. This is fortunate, for a single heat treating process can then be used to minimize both aging and time lag.

Only recently has it been recognized that this lag effect is identical to creep measured under steady loads at high temperature. McVetty[20] reports creep curves at elevated temperature very similar to the lag curves reported for springs at normal temperatures.[10] As suggested in a discussion by Sayre[21] of McVetty's paper, the behavior of these creep test specimens should be determined at normal temperature and at one or two intermediate temperatures. This procedure, it is predicted, will show that the normal temperature lag merges gradually into the high temperature creep. In reply to a suggestion by the author[21] that this high temperature creep was not permanent as usually assumed, McVetty[21] states, "In general, it appears that a creep test conducted at the maximum service test may lead to unduly conservative working stresses if no allowance is made for periods of less severe operating conditions." The instrument designer and user will recognize in this statement the well-known phenomenon that elastic elements show more lag at slightly higher service temperatures.

MANY CONDITIONS AFFECT LAG

Of course, the designer's aim is to produce a lag-free element using heat treatment only as a final corrective measure. A review of the various investigations relating to time lag indicate that residual stresses—and therefore time lag—are controlled by: composition, mechanical condition of the material, rolling or other cold working in the manufacturing process, and the temperatures of fabrication, storage, testing and subsequent service. Of these factors, cold working and temperature are the most important, representing the greatest opportunity for improvement. By control of shop processes and the use of a stabilizing heat treatment (see Fig. 4) the lag effect can be reduced under some conditions to 1% of its original amount. Additional but less effective reductions can be obtained by reducing working stresses as well as by limiting the length of time the elastic element is under load.

Since lag increases rapidly as the operating temperature approaches the annealing point, a composition providing a greater spread between service and annealing temperatures has less lag. Although there is but little information on this point, it is here that the most favorable opportunity exists at present for further refinement after full advantage is taken of heat treatment, shop control, minimum working stresses and reduced operating temperature.

Among the several attempts to explain lag effects, the most successful one to date is given in Sayre's paper "Laws of Elastic Behavior" presented at the 1933 annual meeting of the American Society of Mechanical Engineers.* According to Sayre, isolated slip in unfavorably situated crystals is responsible for changes occurring at light loads, while heavier loads produce fragmentation on slip planes or at the boundaries of these crystals. Upon removal of load, adjacent undeformed crystals compel the unfavorably situated crystals to undergo slip in the opposite direction. Time lag is explained as the result of a probability relation, assuming that slip occurs by small steps only at times when individual atomic positions are favorable. Sayre's hypothesis as explained in his complete paper seems to fit all the facts very well.

Of the two types of lag, the instantaneous or back-lash type is relatively small and is a function of the composition and load stress. Time lag may be relatively large and is a function of residual stresses, temperature and load stress as well as time. Corrective measures applying to the first type are limited, while a number of steps are available for reducing time lag, each of these steps at the same time reducing aging effects.

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14 *A. S. M. E. Transactions*, Vol. 48, 1926, pages 479-500.
15 *A. S. T. M. Proceedings*, Vol. 31, Part II, 1931, pages 157-171.
16 *Philosophical Magazine*, Vol. 37, 1869, pages 65-73.
17 *Report No. 165*, National Advisory Committee for Aeronautics, 1923.
18 *Report No. 371*, National Advisory Committee for Aeronautics, 1930.
19 *Report No. 420*, National Advisory Committee for Aeronautics, 1932.
20 *Mechanical Engineering*, Vol. 56, March 1934, pages 149-154.
21 *Mechanical Engineering*, Vol. 56, June 1934, pages 364-366.

* This paper will appear in the A.S.M.E. *Transactions* in 1934.

LETTERS TO THE EDITOR

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Wattmeters and Power Measurement

By PERRY A. BORDEN† and M. F. BEHAR**

1. Principles

Indicating wattmeters, as now built, utilize almost exclusively the electrodynamic type of measuring element. Up to a few years ago the induction principle was also commonly used; but in present-day practice it finds its only widespread application in a.-c. watthour meters, where it has reached a high degree of refinement. The electrodynamic type of movement, as was pointed out, embodies a stationary coil or group of coils, providing a magnetic field; and a moving coil free to move to a limited extent in this field. The reaction between the two systems being at any time proportional to the product of the instantaneous values of the currents flowing in their circuits, it follows that if one coil be caused to carry a current representative of the voltage, and the other a current representative of the current in the circuit, the reaction between them at any instant will be proportional to the value of the watts in the circuit. It therefore follows that over a period of time the *mean* value of the reaction between the fixed and moving elements will be directly proportional to the power in the circuit without respect to wave form or to the time-phase angle between the respective magnitudes. The mean value of the reaction, of course, is the *torque*. It is measured with one or more springs; therefore the notes on springs at the end of the preceding article are applicable.

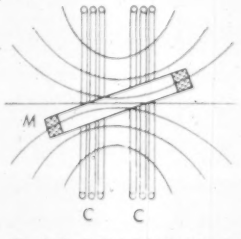

Fig. 34-1. Radial field due to short current coil (Edgcumbe).

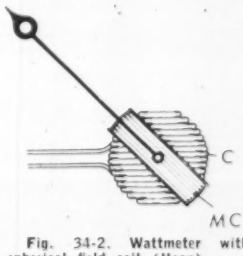

Fig. 34-2. Wattmeter with spherical field coil (Heap).

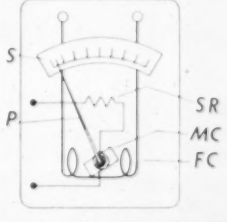

Fig. 34-3. Elements of the indicating wattmeter. FC—field (current) coils; MC—moving (voltage) coils; SR—series resistor; P—pointer; S—scale.

In practice, the fixed coil is usually caused to carry the line current, either directly or through a suitable current transformer, while the moving coil, in series with a relatively high resistance, has impressed upon it the line voltage or the voltage across the terminals of the load to be measured. (Mechanically, the fixed current-carrying and field-producing element is usually a *pair* of heavy-wire coils but these are co-axial and in series so that—electrically—they are one.) While the inherent tendency of electrodynamic *ammeters* to produce a quadratic scale must usually be compensated for to obtain reasonable proportionality, the natural tendency in the electrodynamic *wattmeter* is to produce a scale which would be uniform were it not for the geometrical changes as the deflecting member moves to various positions. In the design of such instruments it is customary to proportion and dispose the parts in such a manner as to retain as far as possible the property of uniformity. This is accomplished by so forming the stationary coil that the moving coil will swing in a nearly radial magnetic field. In most American instruments this condition is approximated by making the axis of the field coil relatively short as compared to its diameter, as shown in Fig. 34-1, while in some European instruments the field coil is wound in a spherical shape and located within the moving coil, as shown in Fig. 34-2.

The above applies not only to single-phase wattmeters but to "polyphase"

*Sixth chapter (XXXIV) of Part Seven (Handbook of Industrial Electrical Measurements and Control) of Béhar's *Manual of Instrumentation*. See editorial announcement of this series on page A7 of November 1933 *Instruments*. A complete chapter of this new handbook will be published in each issue of *Instruments* throughout 1934 and 1935. Each chapter is subjected to a final revision, and then set in type, shortly before its appearance in this serial form, in order to assure that the subject matter is thoroughly up-to-date. This new book is not published serially in any other periodical. Entire contents copyright. To be issued in book form on or about Jan. 1, 1936.

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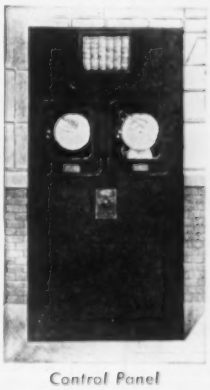

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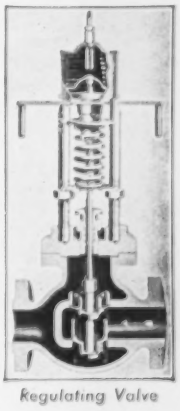

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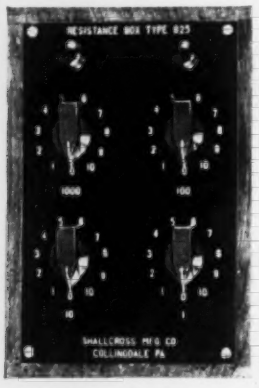

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wattmeters, consisting essentially of two single-phase wattmeter elements with a common shaft, pointer and scale (discussed in Section 7 below).

2. Ratings, etc.

In the foregoing descriptions of voltmeters and ammeters nothing was said about the limits of their ranges because both ammeters and voltmeters have been developed which in conjunction with transformers or amplifiers are capable of measuring over the entire range required not only in engineering but in pure science. Thus there are electrostatic voltmeters for the highest and potentiometers for the lowest potential differences which are desired to be measured, and for current there are special instruments known as surge-crest and lightning-bolt ammeters and there also are instruments known as electron counters.

But power being the product of current and voltage, a single instrument designed to measure the power in a circuit must be suitable at the same time for the values of the current and of the potential difference in the particular circuit under measurement. Theoretically it may be possible to construct wattmeters which would be suitable for the measurement of the short-circuited power of a hypothetical storage battery delivering tens of thousands of amperes at a pressure of one volt; or to construct one for measuring the power of a discharge from an "artificial lightning" apparatus. Such wattmeters, however, would decidedly be freaks; and their use would be confined to highly specialized research laboratories. The current-carrying capacity of a wattmeter is subject to mechanical limitations in the construction of the current coil, particularly with reference to a proper distribution of current density; and the potential circuit is restricted by electrostatic effects, necessitating elaborate systems of shielding. Wattmeter circuits for either voltage or current of extremely high values require that provision be made for dissipating the heat developed; and cooling systems must be added to the already complicated design. While wattmeters have been constructed for several thousand amperes and also for several thousand volts (never, however, in the same instrument) it may be said that 300 amperes marks the practical limit of wattmeter current-carrying capacity and 750 volts the practical voltage limit, and that such magnitudes in the instrument proper should wherever possible be avoided. Instrument transformers obviate as a rule the necessity for wattmeters of extremely high ratings.

Since many loads (such as the iron losses of transformers) have a very low power factor, there have been made available wattmeters of the type known as the "low power factor" instrument. The mechanical control force is made weak in proportion to the electrical carrying capacities of the circuits, so that a full-scale torque may be obtained with an actual power load far below that represented by the current and voltage rating of the instrument. A common rating for such instruments permits a full scale deflection with rated voltage and current at 20% power factor.

Wattmeters having a full scale of less than 15 watts are distinctly in the category of laboratory instruments, and their use is generally limited by pronounced restrictions.

3. Connections—General

NOTE ON DIAGRAMS—The apparent lack of consistency in the methods of representation used in the twenty-five diagrams illustrating this chapter is not accidental. To be sure, there are standards (partially developed at least) for representing instruments in circuits, and we use them in other chapters; but symbols lack details and treat instruments as incidentals. Where instruments themselves are the subject of discussion there are no hard and fast rules for their representation. Moreover, we find it useful to reproduce manufacturers' diagrams and this precludes uniformity. Different makers have standardized neither on methods of representation of similar elements nor on the arrangement of instrument terminals. The authors' method of distinguishing between current and voltage circuits, etc. was simply adopted as a good one for illustrating the present text—not as the universally "best" one. (See Figs. 34-3, -6, -8, -12, -20, -25, -26 and 27.) Most of the other diagrams are reproduced from Weston instruction books, some of them with slight modifications.

In the connection of its measuring system to the circuit under measurement, the wattmeter possesses the elements of both the ammeter and the voltmeter. The fixed coils, as already stated, are made to carry the line current or a current representative of it, either by being connected in series with the line or, in a.-c. installations, by being fed through a current transformer of suitable ratio. Portable wattmeters may be obtained with their current coils wound for a variety of current ranges; and two-range wattmeters, arranged to have the two parts of the current coil connected either in parallel or in series, are common and useful instruments. Switchboard wattmeters are practically always wound for 5 amperes in the current coils. In modern practice wattmeters are not used often on d.-c. loads; and the shunting of a wattmeter current coil for a.-c.

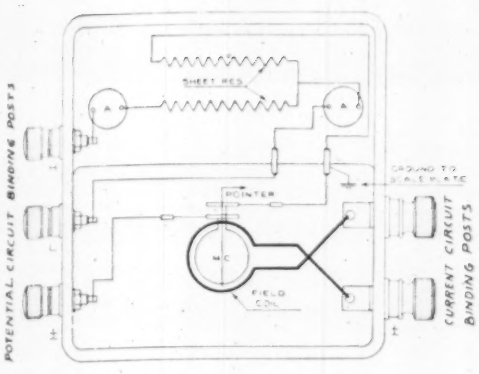


Fig. 34-4. Internal connections of Weston Model 432 wattmeter.

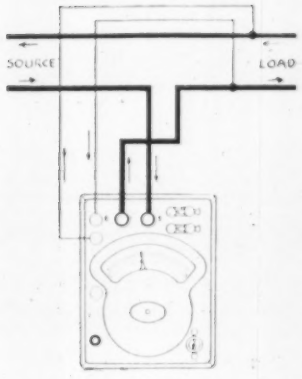


Fig. 34-5. Single-phase wattmeter connected directly to line (Weston).

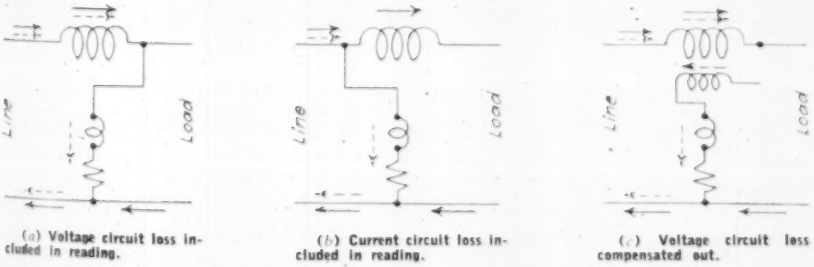
work is likely to be productive of serious errors due to phase displacement of the current in the field windings.

The moving coil of an electrodynamic wattmeter, being made up of fine wire, is readily connected across the circuit through a series resistor, voltage transformers being used or not according to the voltage of the system. In well designed wattmeters, care is exercised that the voltage circuit be substantially non-inductive or that an equivalent compensation be applied, whereby the phase-angle between the magnetic fluxes produced by the two electromagnetic elements will be the same as that between current and voltage in the circuit under measurement. If this refinement is not observed, the *accuracy* of a wattmeter, whatever its precision, will vary with different power factor values of the measured load.

Portable wattmeters, like portable voltmeters, are frequently furnished with several voltage ranges by bringing out taps from a series resistor to suitable binding posts. As in the voltmeter, an external *resistor* is not correctly termed a *multiplier* unless the instrument is complete and gives a correct scale indication without its use.

4. Instrument Losses

When a wattmeter is connected in a circuit where power is to be measured, we have exactly the same condition as is found in the simultaneous connection of an ammeter and a voltmeter. The reading of the wattmeter will differ from the true power by an amount equal to the power consumption of either the current coil or the voltage circuit of the instrument. If the voltage terminals are taken off the "load" side of the instrument, as at *a*, Fig. 34-6, the indication will include the power consumption of the voltage circuit, while if they are connected to the supply line, as at *b*, the actual power represented by the load will be less than the reading on the scale by an amount equal to the power consumption of the current coil. Each of these circuits consumes a few watts (their total may amount to 5 watts in indicating instruments) so that in the measurement of small loads they may need to be taken into consideration; but where instrument transformers are employed, as in industrial work, it is the general practice to ignore their values. Where it becomes necessary in the use of a simple wattmeter to take these losses into consideration it is the better practice to connect the instrument so that the voltage coil losses are included in the reading as at *a* in Fig. 34-6. These losses may be computed more easily than the current coil losses, and may be deducted from the reading of the instrument.



(*a*) Voltage circuit loss included in reading.

(*b*) Current circuit loss included in reading.

(*c*) Voltage circuit loss compensated out.

Fig. 34-6. Losses in the wattmeter. Full arrows indicate flow of load current; dotted arrows indicate flow of voltage coil current.

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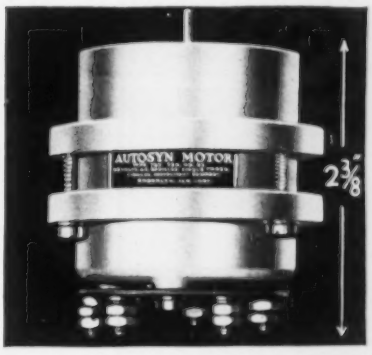

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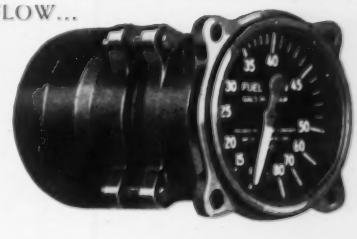

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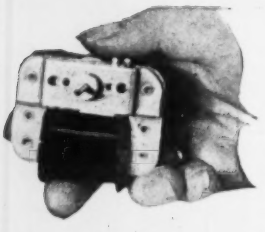

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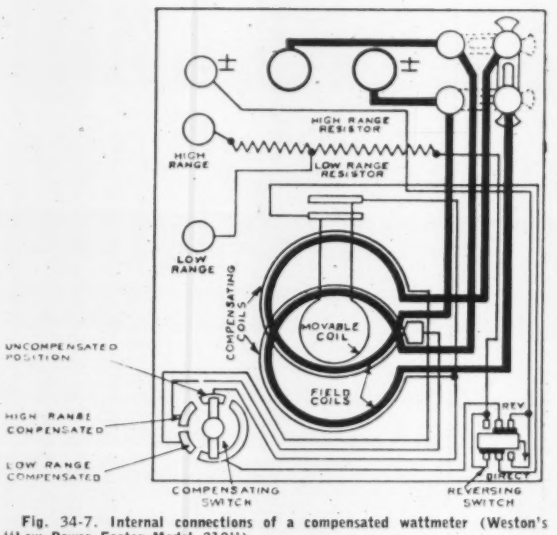


Fig. 34-7. Internal connections of a compensated wattmeter (Weston's "Low Power Factor Model 310").

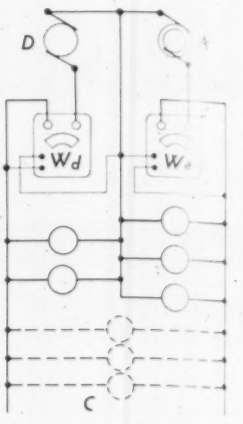


Fig. 34-8. Total power in a three-conductor circuit measured on two wattmeters.

D—Source of d.c.
A—Source of a.c.
C—Mixed load.

5. Compensating Coils

There are available portable instruments having a compensating circuit which automatically corrects for power loss in the voltage coil by providing a connection equivalent to that shown at c in Fig. 34-6. The internal connections of a Weston single-phase wattmeter embodying this principle are shown in Fig. 34-7. The compensation is effected by means of a winding (marked "compensating coils") connected in the voltage circuit, having the same effective number of turns as the field coil, and wound in such a direction that the current in it is opposite to that in the field winding. The current taken by the potential coil, flowing in this auxiliary winding, exactly neutralizes the effect of the same current flowing in the main field winding, so that the net effect of the voltage circuit current upon the indication of the instrument is nil. As the instrument shown has also provision for connecting two sections of the current coil either in parallel or in series, thus providing two current ranges, the auxiliary coil is similarly subdivided and connected to a compensating switch, which must be set to correspond to the current coil connections. This switch has also a third position, in which the compensating winding may be cut out of circuit when using the wattmeter with instrument transformers or when checking the accuracy of other instruments or when the wattmeter itself is being checked (or in other work where the compensating coil is superfluous).

6. Polarity Precaution

The connections of a wattmeter to a circuit should be made in such a manner that no appreciable potential difference exists between the stationary and moving coil. Such a potential may cause errors due to electrostatic stresses, beside endangering the insulation where clearances are very small. An instrument used without transformers should have the moving coil of the voltage circuit connected to the same conductor as that in which the current coil is placed, the series resistor being connected to the other side of the circuit. Most makers provide distinct markings whereby the sides of the voltage circuit may be identified and properly associated with the current coil.

7. N-wire Circuits

(a) Principle

The whole power in any two-wire circuit will be measured by a wattmeter having a single current coil connected in series with either side of the line, and its voltage coil connected across the load, as in Fig. 34-5. It may be proved mathematically* that in *any* electrical circuit of n conductors the whole amount of power passing through the system may be measured for any condition by n-1 wattmeter elements having their current coils in series with n-1 of the line conductors and their voltage circuits connected from the lines corresponding to the respective current coils to the one conductor which does not pass through any current coil.

It is interesting to observe that this fact regarding power measurement holds true however different in magnitude, wave-form and phase position may be the currents in the several conductors. In fact the currents need not be of the

*Karapetoff. *Experimental Electrical Engineering*, 3rd Ed., Vol. I, page 131, par. 101.

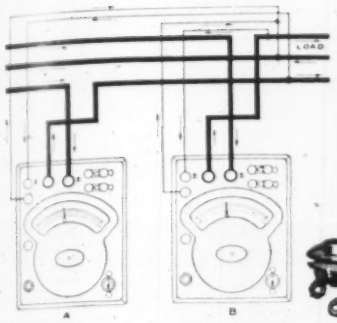


Fig. 34-9. Two-wattmeter method of measuring power.

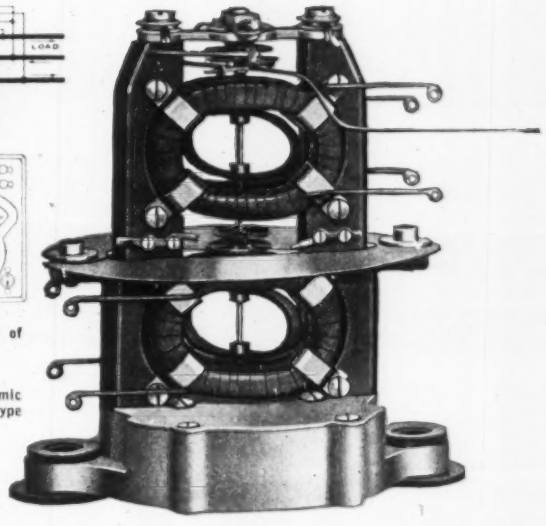


Fig. 34-10. (at right) Electrodynamic measuring element of Roller-Smith "Type GSA" polyphase wattmeter.

same frequency; and as an extreme instance may be cited a system of conductors in which some of the currents are direct and some alternating, when it will be found that the total of the measurements of the several wattmeter elements is still in proportion to the value of true power in the circuit. Such a case is shown in Fig. 34-8, where a d.-c. supply D and an a.-c. supply A have a common conductor. The wattmeter W_d, connected as shown, will measure the d.-c. power, and the wattmeter W_a, the a.-c. power, so that the sum of their indications will represent the total power in the three-conductor circuit. Moreover, if a load be connected between the two remaining wires, as at C, the power consumed thereby will be a mixture of d.-c. and a.-c. of which the former component will be measured on the instrument W_d and the latter on W_a, so that the total will remain correct, and the sum of the indications of the two instruments will continue to represent the total value of power in the system.

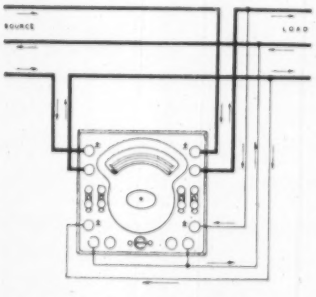


Fig. 34-11. Connection of a polyphase wattmeter to a 3-conductor system.

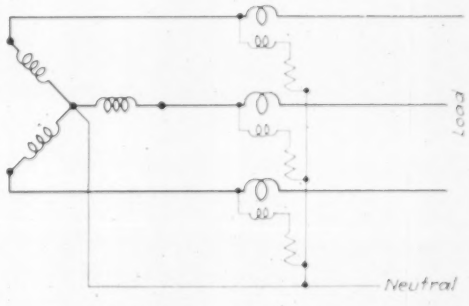
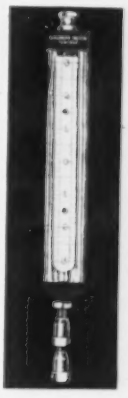


Fig. 34-12. Three-wattmeter method of power measurement.

(b) Two-wattmeter Method

The most common application of this principle is found in the "two-wattmeter method" of measuring power in a polyphase three-wire system by means of two single-phase wattmeter elements, the connection being as shown in Fig. 34-9. This practice is universal to a degree that the "polyphase" wattmeter, consisting of two single elements on a common deflecting shaft, is widely employed for electrical testing and for switchboard installations, and is probably in more general use than is the single-phase instrument. Fig. 34-10 shows the measuring element of such an instrument; and the basic connection diagram of a polyphase wattmeter is shown in Fig. 34-11. While an analysis of circuit conditions will show that on a polyphase load the power factors of the loads in the respective elements may differ from each other and from that of the total load, it will not alter the fact that the total load in the circuit is represented in magnitude by the wattmeter reading: the principle of the method of measurement automatically allows for divergence of phase angles in the individual elements.

PROTECTOR*



SIPHON PRESSURE GAGES

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MANUFACTURERS' NEW LITERATURE

In this department we each month list the printed matter issued by manufacturers. Unless otherwise noted, any of the items listed may be secured free upon application to the issuing firm. Manufacturers who have not yet sent in their printed matter are invited to do so.

B172 **General Radio Experimenter.** The March 1934 issue contains the following articles: The Measurement of a Small Inductance; Constant-Inductance Resistors; Taking Slow-Motion Movies with an Ordinary Motion-Picture Camera. General Radio Company, 30 State St., Cambridge A, Mass.

B173 **Adjustment and Operation of Modulators.** A booklet of operating data telling how to measure modulation accurately so as to prevent distortion, over-modulation and other inherent troubles of poorly designed and improperly operated 'phone rigs. Westinghouse Elec. & Manufactiring Co., East Pittsburgh, Pa.

B174 **Quiet Operating Motors.** In buildings such as schools, churches, hospitals, hotels, apartment buildings, libraries, and in many parts of large public buildings it is essential that there be no objectionable noise. This 4-page leaflet describes the method of individual testing of these motors for quietness, their distinctive features, construction, application and control. Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

B175 **Electric Drying Oven.** Leaflet describes the automatically controlled electric drying oven of E. H. Sargent & Co., 155 E. Superior St., Chicago, Ill.

B176 **Stirring Motor.** The Sargent cone drive stirring motor is adapted to all general requirements for agitation and motive power, and is particu-

larly fitted for rotating electrodes, driving calorimeter stirrers, etc. E. H. Sargent & Co., 155 E. Superior St., Chicago, Ill.

B177 **The Mainspring.** The March 1934 issue of this house organ contains the following: "A Table of Physical Properties of Spring Steels" and "Can Production Lines be Far Behind?" Wallace Barnes Co., Bristol, Conn.

B178 **Rheostats.** The April issue of the Ohmite News illustrates the complete line of Ohmite all-porcelain vitreous enameled rheostats. Ohmite Mfg. Co., 636 North Albany Ave., Chicago, Ill.

B179 **Cooking Thermometer.** Attractively printed leaflet lists the 12 features of the new Taylor thermometer. Taylor Instrument Cos., Rochester, N. Y.

B180 **Resistance Thermometer.** Catalog 9001, a new 32-page catalog featuring the Brown resistance thermometer for measuring temperatures from —300° to +1000°F. Brown resistance thermometers are available in indicating, recording and controlling types and have many new and improved features such as: Universal case; electric chart drive; combination door handle and lock, and toggle switch for chart drive. Brown Instrument Co., 4482 Wayne Ave., Philadelphia, Pa.

B181 **Thermostatic Valve.** 4-page bulletin describes the Lawler thermostatic tempering valve for submerged coil type heater, etc. Lawler Automatic Controls, Inc., 50 Putnam St., Mount Vernon, N. Y.

B182 **Controllers.** Bulletin C, 24 pages on float type liquid level controllers. Kieley & Mueller, Inc., 34 W. 13th St., New York, N. Y.

B183 **Control Relay.** Bulletin 20 describes the Faratron "invisible control" relay. Lumenite Electric Co., Old Colony Bldg., Chicago, Ill.

B184 **Thermostat.** Bulletin 67 illustrates and describes the No. 261 Cabinet Thermostat for enclosure type heating, cooling and air conditioning units. Detroit Lubricator Co., Trumbull and Lincoln, Detroit, Mich.

B185 **Cenco News Chats.** The April issue of this house organ contains considerable information on the activities of the Central Scientific Co., Chicago, Ill.

B186 **Comfortrol.** Bulletin C describes the Comfortrol, a device which embodies a temperature sensitive element and a relative humidity sensitive element so interlinked that it is possible to vary the ratio of 2 factors of temperature and humidity going to make up effective temperature. Julien P. Friez & Sons, Inc., Baltimore, Md.

B187 **Gage Blocks and Accessories.** Catalogue No. 10, a 36-page book, lists the various gaging system sets, and accessories. Prices are given. Ford Motor Co., Johansson Division, 3674 Schaefer Road, Dearborn, Mich.

B188 **Microscope Illuminators.** 16-page booklet describes the various types of microscope illuminators. Bausch & Lomb Optical Co., 635 St. Paul St., Rochester, N. Y.

B189 **Thermostatic Expansion Valve.** Leaflet describes the type No. 674 thermostatic expansion valve. Detroit Lubricator Company, Detroit, Mich.

B190 **Baloptícons.** 6-page leaflet illustrates the automatic baloptícon. Bausch & Lomb Optical Co., Rochester, N. Y.

INSTRUMENTS, 330 W. 42nd St.
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(c) Special Connections

The diagram shown in Fig. 34-11 may also be applied to the measurement of the total power in a d.-c. or single-phase three-wire system, or in a two-phase three-wire circuit. The two-element wattmeter also provides means for performing with a high degree of flexibility practically all measurements which may be made with a single-phase instrument. Some of these applications are shown in Figs. 34-13 to 34-19, inclusive; and others will suggest themselves to

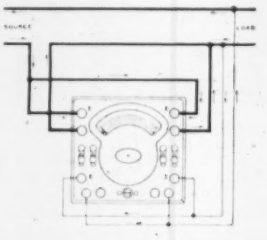


Fig. 34-13. Current coils in parallel, giving a total current capacity equal to that of both coils.

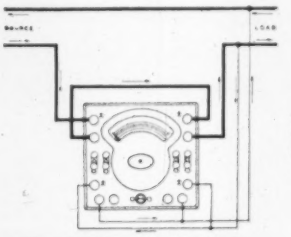


Fig. 34-14. Current coils in series. Total current should not exceed carrying capacity of each individual coil. This connection to be used for low wattages, and readings should be multiplied by 0.5.

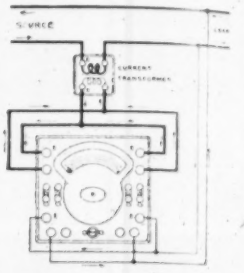


Fig. 34-15. Instrument connected to line through a current transformer, current coils in parallel.

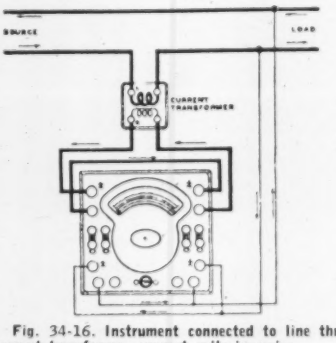


Fig. 34-16. Instrument connected to line through a current transformer, current coils in series.

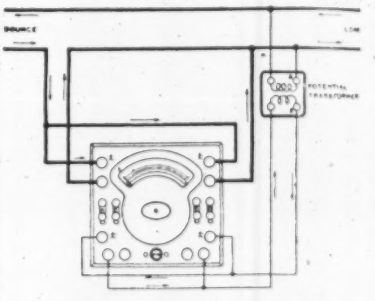


Fig. 34-17. Instrument connected to line through a voltage transformer, current coils in parallel.

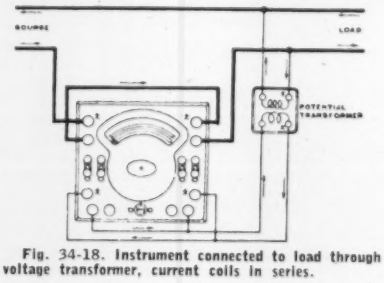


Fig. 34-18. Instrument connected to load through a voltage transformer, current coils in series.

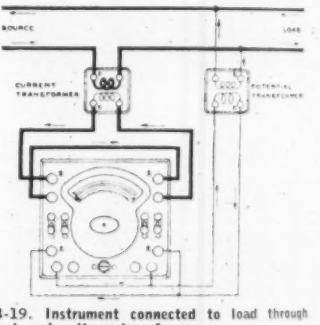


Fig. 34-19. Instrument connected to load through both current and voltage transformer.

APPLICATIONS OF TWO-ELEMENT WATTMETER ON TWO-CONDUCTOR CIRCUIT.

the experienced user. An interesting application of the two-element wattmeter is found in the determination by a differential system of measurement, of power losses in transformers, motor-generators or other pieces of apparatus in which both input and output are carried in a two-wire circuit. A typical connection for this purpose is shown in Fig. 34-20. A two-element portable wattmeter is connected so that the d.-c. input to a small motor-generator set passes through one element of the instrument in a sense to give a positive reading, and the single phase output passes through the other element in a reverse sense. If the switch S in the voltage circuit of the output side be opened, the wattmeter will indicate the input to the machine. When the output side is made operative the reading will decrease by an amount representing the value of the output, and the losses will be indicated on the scale. With a high-grade instrument, this method makes efficiency determinations more simple and more accurate than when separate measurements of input and output are made.*

*For amplification of this method see the following articles by Borden: Determination of Transformer Losses, *Electrical World*, Vol. 68, 1916, page 716; Measurement of Maximum Demand, *Transactions A. I. E. E.*, Vol. 39, 1920, Fig. 1, page 1851; Balance Methods in A.-C. Measurements, *Transactions A. I. E. E.*, Vol. 42, 1923, Fig. 9, page 400.

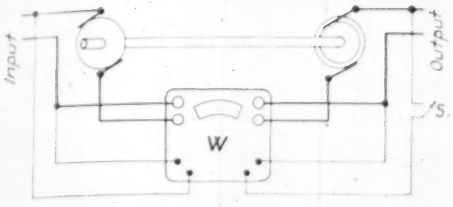


Fig. 34-20. Determination of losses in motor-generator set with two-element wattmeter.

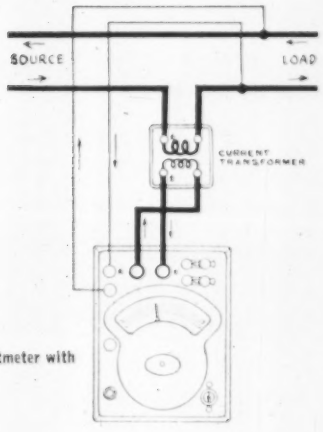


Fig. 34-21. Single-phase wattmeter with current transformer.

(d) Wiring

In the April article on Instrument Transformers it was stated that in the connection diagram the instrument transformer might be treated as though it were replaced by a resistor. Comparing the diagrams shown in the present chapter, it will be noted that in those instances where two diagrams differ only in the presence or absence of instrument transformers, as Figs. 34-5 and 34-22, the transformers could be replaced by resistance units without affecting the polarities of the connections. In those diagrams which are given for portable instruments, the secondary leads from different instrument transformers are generally kept separate, while with switchboard instruments, common wires are used fairly frequently. The principal reason for the latter practice is one of economy; and where the use of common wires does not interfere with accurate metering, considerable savings in conductor and conduit may thus be effected. See Fig. 34-25. While it is good practice to ground the secondary circuits of both voltage and current transformers, thus reducing both systems to a common potential, it is unwise to use a single conductor as a common return for both sets of wiring. If this is done, the potentials due to secondary currents flowing through the resistance of the common wire may be superimposed upon the secondary network in a manner to cause considerable errors in the indications of the connected instruments.

(e) Three-wattmeter Method

While the general formula for measurement of the total power in a circuit of n conductors requires a wattmeter system having n-1 current coils, there are a number of special cases where, with limitations, simpler forms of instruments may be used. It is evident that the total output of a three-phase generator will be correctly measured by three single-phase wattmeters connected in the three line wires, with their voltage circuits connected to the neutral point of the generator, Fig. 34-12, whether the neutral conductor be carrying current or not. It is further evident that, so long as the currents in the three phases are of equal magnitude, giving a balanced load, the readings on the three instruments will be equal in value, and that therefore two of the units may be removed and the indication of the remaining instrument multiplied by three to obtain the total load. So-called "balanced load" wattmeters, having their scales calibrated

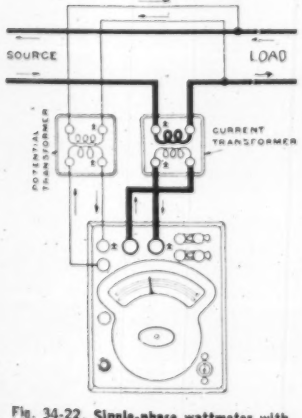


Fig. 34-22. Single-phase wattmeter with both current and voltage transformers.

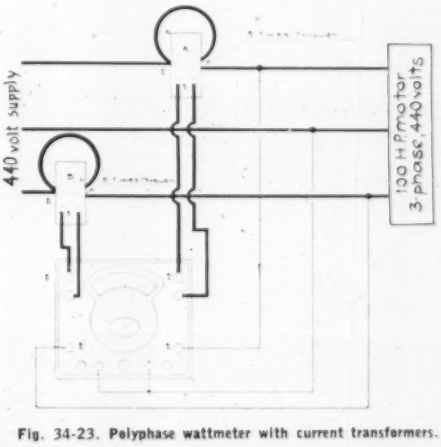


Fig. 34-23. Polyphase wattmeter with current transformers.

NEW INSTRUMENTS

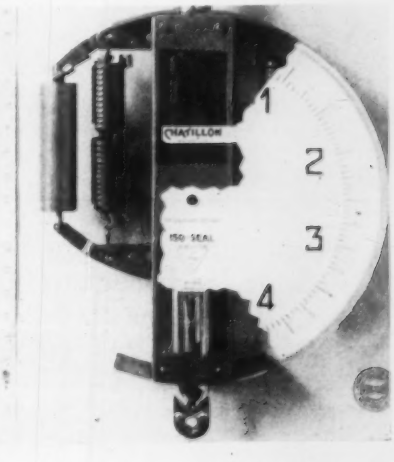
Write Information Section, Instruments Publishing Company, for additional information.

Precision Spring Scales

John Chatillon & Sons

FIVE years' research and development have resulted in this new spring scale, said to minimize or eliminate altogether some errors which, in previous designs and with previously-used materials, arose from four sources: (1) Spring material, (2) spring design, (3) mechanism, (4) parallax. In this work, the efforts of A. V. deForest, consulting metallurgist, and of Prof. M. F. Sayre of Union College, were combined with those of the manufacturer's research and development staff. The new springs are called "Iso-Elastic"; the new scales "Iso-Seal."

1 & 2. Reduction of Spring Errors — Deviations from true load-deflection proportionality fall into four types: (*a*) Temperature coefficient of the modulus of elasticity. Usually compensated by the use of a bimetallic element, but this may introduce new errors. (*b*) Non-proportionality between stress and strain at all loads. Usually corrected by hand-graduated dials, hand-adjusted racks or linkages, etc. (*c*) Creep under constant load, or lag of strain in relation to stress, causing a slow increase in scale reading. With hardened steel springs working at maximum fiber stress of 50,000 lbs./in.^{2} this error may reach 0.5% in 24 hours, the greater part of the creep occurring during the first few minutes. (*d*) Hysteresis or "back error," manifested in step-by-step loading and unloading curve forming a loop instead of a single line; this effect, independent of the lag error, varying widely — it may be about 0.25% of the maximum deflection. *Temperature error* (*a*) is absent in a new ferrous alloy of the Elinvar type, developed under the direction of Mr. deForest, containing 36% Ni, 8% Cr, with a total of 4% of other elements including Mn, Si, Mo, Cu and Va. Cold-drawing reduces area about 90% and increases safe working stress from 12,000 to 60,000 lbs./in.^{2}, then a moderate-temperature heat-treatment stabilizes the spring, reducing *creep error* (*c*) to less than 0.02% and *back*



error (*d*) to less than 0.04%. *Errors of non-proportionality* (*b*) are minimized by new design resulting from mathematical analysis by Prof. Sayre who proved that in helical springs they are the product of three factors:

$$(b) = \frac{P R_o^2}{3GJL}\left(3 - 2\frac{GJ}{EI}\right)(H^2 + HH_o - 2H_o^2)$$

where P = load on spring; R_o = initial radius of coil; E = tension modulus; G = torsion modulus; I = moment of inertia in bending; J = stiffness factor of wire in torsion (polar moment of inertia for round wire); L = developed length of wire in spring; H = total height of effective portion of spring; and H_o = initial height of effective portion of spring. The first and third factors can be controlled in the general design of the spring but neither can be reduced to zero. By properly choosing the shape of the wire in relation to the elastic constants of the material, the factor GJ/EI can be made to equal 1.5 and the theoretical deviation throughout the full range of the spring made equal to zero. This calls for a wire with a rectangular cross section. Since, however, the elastic constants differ slightly from wire to wire and since the behavior is also affected somewhat by variations in the values of G and E under load, each spring represents a complete design problem starting from the original equation. Application of this method is said to reduce non-proportional deviations (*b*) to less than 0.01%. Since a helical spring twists as it extends, additional errors are introduced by *friction* at the end supports. In the "Iso-Seal" scales the "Iso-Elastic" springs are each made up of two springs coiled in opposite directions (see photograph) so that the twist of the pair at its supports is zero. *Final result:* The total deviation due to (*a*), (*b*), (*c*), (*d*) and coil twist, is said to be $<0.08\%$. Manufacturers report also that new springs "have shown no fatigue after a million rapidly repeated deflections."

3. Mechanism—To utilize new springs to full advantage, manufacturers developed new type of scale mechanism. This phase of the research entailed "a radical revision in manufacturing practices," in which accurate tools of mass production were substituted for dependence on highly skilled handicraft. The entire apparatus consisting of transmitting and indicating systems and including pinions, racks, and dials, accurately meets conditions of no load, part load, and full load, it is said, better than previous handiwork. The novel dash-pot, used to cushion shocks of sudden loads and to bring pointer to full stop within a second, is believed to have applications other than in weighing apparatus.

4. Parallax—This error occurs frequently in use because few scale users are trained to sight perpendicularly to dial. It has been minimized by locating in one plane the pointer and the graduated outer dial surface.

Temperature Controller for Variable-load Processes

Emil T. Johnson Regulator Co.

THREE bulbs connected to one controller body—such is the novel arrangement of this new self-operating temperature controller for steam-heated continuous processing equipment such as

in terms of total load, and intended for this type of connection, are available, and have found a considerable application, particularly in European practice; but, since any type of inequality among the several phases will introduce errors, instruments which require a balanced load on the system should be looked upon with suspicion.

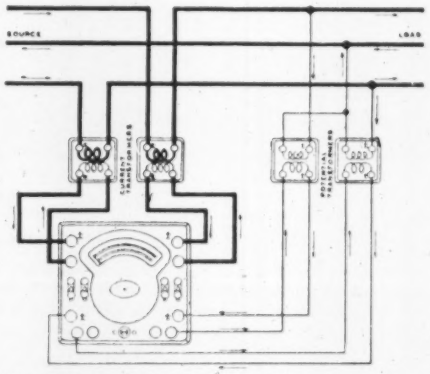


Fig. 34-24. Polyphase wattmeter with both voltage and current transformers.

(f) Four-wire Systems

While a strictly accurate determination of the total power in a three-phase *four*-wire system would require the three-wattmeter method shown in Fig. 34-12, it is possible to perform a satisfactory measurement of such a load under most conditions with a two-element instrument. This is done by passing through each of the current coils in the wattmeter the resultant of currents in two conductors, and connecting the voltage circuits from two lines to the neutral of the system. See Fig. 34-27. Because each current coil is required to carry the resultant of currents flowing in conductors which are at different potentials, it is essential in this method that current transformers be used, whatever the magnitude of the load. With this system each of the two wattmeter elements is caused to measure not only the power in its corresponding phase, but a portion of the power in the remaining phase. With the delta connection of current transformers, each element of the wattmeter receives the resultant of two of the line currents—one of these corresponding to the voltage upon that element, and the other (reversed) to the potential which is not carried into the

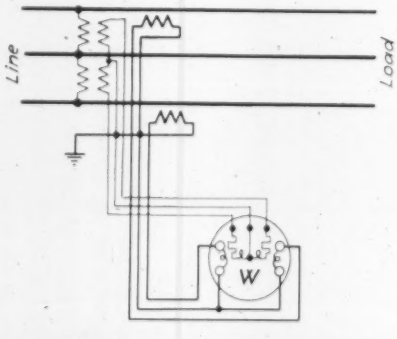


Fig. 34-25. Connections of switchboard wattmeter, using common wires in instrument transformer circuits.

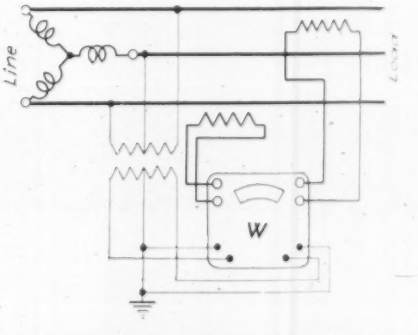


Fig. 34-26. Measurement of power in 3-phase, 3-wire system, using instrument transformers, with common wire in voltage transformer secondaries.

wattmeter. Thus each current coil carries a current which is the vector difference of two of the line currents. On a balanced load at unity power factor each of the currents would be equal to $\sqrt{3}$ times the current in a single transformer, and the currents would be 60° apart.

If the voltage in the third phase is the reversed resultant of the voltages in the other two phases, the latter will have the same effect upon the component of current from that phase which flows in the two current coils as the third voltage would have, were it to act directly upon one coil carrying current from the third transformer. The same result, therefore, is obtained from this combination as would be from three wattmeter elements connected one in each phase of the system.

The wiring diagram for a three-phase four-wire system of measurement may be developed from the three-conductor system in the following simple manner:

(1) Prepare a diagram for the standard method of measuring a three-phase three-wire load with instrument transformers (Fig. 34-26).

(2) Add the neutral of the power system to the diagram, and transfer the common or "middle" potential wire to this neutral.

(3) Add a current transformer on the third of the line wires (in practice, of course, the same ratio as the original transformers).

(4) Without otherwise disturbing the current wiring, complete a delta connection of the three current transformers, thus obtaining the diagram shown in Fig. 34-27.

Some meter manufacturers provide for use on four-wire circuits a self-contained type of watthour meter having an internal connection which is equivalent to that obtained with the delta connection of current transformers described above. A diagram of the Sangamo two-element watthour meter for four-wire circuits is shown in Fig. 34-28. Each element of the meter is equipped with two relatively reversed current windings, so that the net electromagnetic effect due to the joint action of the currents flowing in an element is that which would be produced by the resultant of the two currents (one being reversed) flowing in a single winding in that element. Since this relatively expensive type of construction is not necessary where current transformers are available, the principle is confined almost wholly to use in watthour meters where a maximum simplicity of external wiring is imperative.

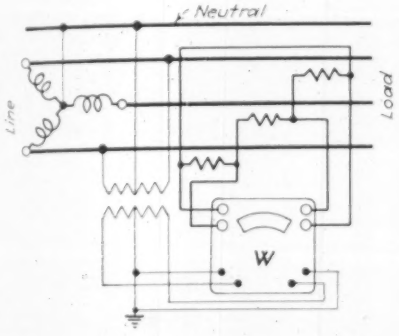


Fig. 34-27. Measurement of power in a 3-phase, 4-wire system, using delta-connected current transformer. Diagram developed from Fig. 34-26.

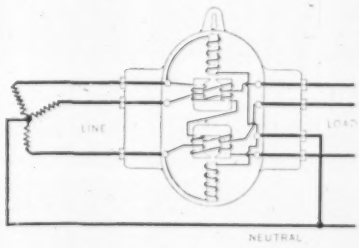


Fig. 34-28. Diagram of internal connections: 3-phase, 4-wire vertical 2-disk type watthour meter (Sangamo).

The legitimacy of the two-wattmeter method of determining the total power in a three-phase four-wire circuit depends upon the vector sum of the three line-to-neutral voltages being zero. These voltages need not be equal, nor need the phase displacements between them be exactly 120 electrical degrees. When a four-wire supply is derived from a three-wire system by a star-delta transformation, the line-to-neutral voltages on the secondary side of the transformers are vectorially similar to the line-to-line voltages on the three-wire side. Since these latter voltages give a closed vector triangle, the secondary voltages satisfy the condition for accurate power measurement however unbalanced may be the primary voltage triangle.*

8. Scale Readings

Portable instruments as commonly used in test work generally have their scales calibrated to read the actual watts in the instrument windings. Where several ranges are provided, as by series-parallel arrangement of current coils, or by several taps on the voltage circuit, or by combinations of the above, either several sets of numerals are associated with a single set of graduations, or else to the basic calibration is applied a multiplying factor suited to the connection used. In a two-element wattmeter the scale reading is of course proportional to the total of the watts in the two individual elements; and if the instrument is properly designed and adjusted the reading will be independent of the distribution of power between the elements. Of course in a two-element instrument having several ranges it is imperative that the two parts of the instrument be set to have the same over-all multiplying factor.

Where a polyphase instrument is used with both current coils in series in measuring a single-phase load, as in Figs. 34-14, -16, -18 and -19, it is important

*Stubbings: *Commercial A-C Measurements*, Page 37.

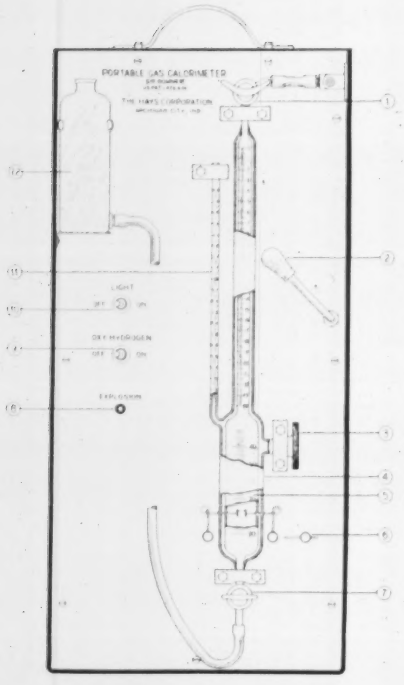
pasteurizers, where fluctuations must not exceed approx. 0.3°F. and must be of short duration when they do occur. Two-bulb and four-bulb models are announced also, but the following description of the standard triple type will bring out the new principle employed equally by all models. Likewise, the following discusses a milk pasteurizer but applies equally to numerous other counter-flow heat-exchange applications in the food and chemical industries, where not even a short portion of the continuously flowing stream is permitted to be overheated or underheated.

The main difficulty in controlling a pasteurizer arises from the impossibility (theoretical and practical) of continuously proportioning the rate of B.t.u. supply to the constantly-varying demand, with only one temperature-sensitive element (bulb, etc.) located in the milk outlet. The chief improvement now announced is the placing of two additional bulbs, in the circulating water inlet and outlet respectively. Obviously, the temperature differential between these two bulbs at any instant represents the "degrees dropped" in heating the milk which is *in* the pasteurizer at the same instant. Interconnecting these two bulbs (whose volumes are equal) results in so controlling the steam supply to the steam-and-water mixing chamber that the return water will "pick up the same number of degrees." Therefore, with these two bulbs alone, variations in the rate of throughput of the milk, and also in the entering milk temperature, are immediately detected and result in an immediate re-adjustment of the steam supply. If radiation losses, steam quality and other factors were constant, this pair of bulbs alone would provide good temperature control. However, in order to compensate for all such variables, a third bulb (of volume depending on the particular application) is located in the milk outlet and serves, it is said, to increase the sensitivity of the entire system to such an extent that control is "practically perfect"—that is to say, even the highest precision open-scale dairy recording thermometers on the market are not sufficiently sensitive to show whatever variations may exist. This third bulb is not located in the milk outlet line outside of the pasteurizer, but it must be located in the last portion of the milk line which is still surrounded by circulating water. When this milk bulb is so installed, the control is said to be so effective that the flow of milk may be stopped altogether, started again, and so on, without appreciable effects being recorded on an open-graduation chart. The body and steam valve of the new 2-, 3- and 4-bulb controllers are similar in construction to those of the single-bulb model (*Instruments*, May 1931, page 97).

Portable Gas Calorimeter

The Hays Corp.

NO special training is required to determine the heating value of a gas by means of this new instrument. The first test on any day takes about five minutes; others the same day from one to two minutes. Only a small sample (5 to 25 cc.) is required. The sample is mixed with air and exploded in a calibrated burette surrounded by a jacket containing a liquid of high temperature coefficient of expansion which the heat of explosion causes to rise in



a capillary. A parallel test can be carried out with oxy-hydrogen (of known heating value) which is generated in the instrument by the electrolytic dissociation of water. Since the two gas samples are tested under the same conditions, no corrections are necessary and the result is obtained through a simple calculation. The Hays Portable Gas Calorimeter may also be used for safeguarding sewage systems by testing the explosive properties of sewage gases; determining explosive limits; adjusting gas burners for correct air-gas mixtures, etc.

Portable Testing Machine for Welding Work

Air Reduction Sales Co.

IN fabrication and in pipe line work, engineers now consider it essential to know the actual strength of welds as they are made. Difficulties of shipping specimens to testing laboratories have created a demand for a compact, accurate and portable testing machine. The Airco Portable Tensile and Bend Testing Machine weighs about 200 lbs. and can be carried to the job, where welded specimens, it is said, can be tested rapidly and easily. It consists essentially of an oil pump, a hydraulically actuated piston or ram, two heads—one fixed and one movable—for gripping the test specimens, and four symmetrically located steel shafts, two of which transmit piston motion and load to movable head. The other two shafts maintain the alignment of the two heads, and prevent introduction of bending stresses in the tensile test specimen. Load on test specimen is indicated on a high-grade 6" pressure gage. With a few strokes of the operating lever, after the specimen is set up, the operator can apply a direct load up to 40,000 lbs. to specimens 10" long, up to ½" thick, and up to 1½" wide. Then, by using specimens of smaller cross-sectional areas than the maximum 1½" by ½", loads equivalent to 150,000 lbs./in.^{2} or higher can be applied, so that all steels can be tested. Stroke of movable head is up to 2¾",

to observe that, since the one load may be said to be *measured* twice in the one instrument, the indication on the scale will be twice that representing the load; so that, after applying such multiplying factors as may characterize the basic connection system, the reading must be halved to obtain the correct result. In an instrument connected on a polyphase circuit, as in Fig. 34-11, the total power in the system is divided into components, each of which is only once subjected to the process of measurement, so that the true power value is represented by the reading on the scale suited to the range for which the instrument is set.

9. Application of Instrument Transformer Ratios

Where instrument transformers are used with a wattmeter, the ratio between the magnitude of the true power flowing in the measured circuit and that in the circuits of the instrument will be equal to the over-all ratio of transformation, or the product of the current transformer ratio by the voltage transformer ratio. For instance, if a wattmeter receives its current through 150/5 current transformers and has its potential coils excited through 2300-115 voltage transformers, the over-all ratio of transformation will be 150/5 × 2300/115 = 600; so that 600 kilowatts flowing in the line would be represented by 1 kilowatt in the instrument. A wattmeter intended to be permanently used with the same instrument transformers, as in switchboard practice, is generally calibrated to give a direct reading of the power in the line. In the above case, while the actual watts in the instrument to produce a full scale deflection would probably be 1000, the scale as calibrated would read to 600 kilowatts. Portable instruments ordinarily require that their scale indications be multiplied by the over-all ratio of transformation; and the statement of an earlier paragraph to the effect that the reading does not require to be corrected for the inherent difference between phase-angle in the wattmeter elements and phase-angle of the measured load is applicable to any of the types of instrument transformer connection described, so that, beyond possible errors in the transformers, the only multiplying factors applicable to the wattmeter readings are those representing the ratio of transformation and the factor associated with the range of the instrument itself. The authors have noted instances where it was thought, because two (or more) current transformers or voltage transformers are used in measurement of polyphase loads, that it would be necessary to apply a multiplying factor of 2 to the transformation ratio. The explanation given above, where it is made clear that each measuring unit measures *but once* its allotment of the load, will serve to show that this is a misapprehension.

10. Selection of Transformers

In the selection of instrument transformers for a given load or circuit it is obvious that the combination should be such as to give a maximum scale indication on the wattmeter without the probability of exceeding the range at times of maximum load. It is not good practice to connect the 5-ampere secondary of a current transformer to a wattmeter current coil intended for a lower range. Voltage transformers should be operated at or near their rated voltage. When a permanent installation is made where it is known that the load will subsequently be increased beyond its present value, it is well, wherever possible, to select current transformers having ratios suited to the initial load, and to change these as the load is increased (changing, of course, the wattmeter scale to correspond). Two-range switchboard current transformers, designed with this practice in view, are obtainable at a slight increase in cost over single-range transformers.

Although most readers may consider it self-evident, it is not superfluous to conclude with the statement that wattmeters, ammeters and voltmeters can all be used simultaneously on the same instrument transformer installation.

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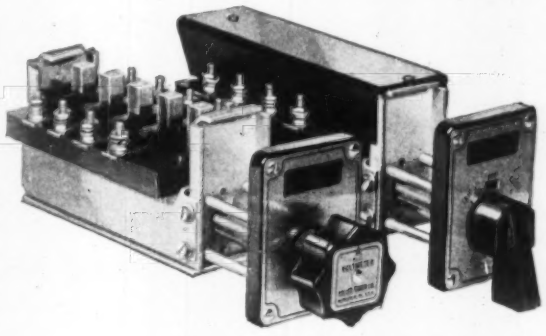

At left, instrument switch, cover removed. At right, control switch, cover in place.

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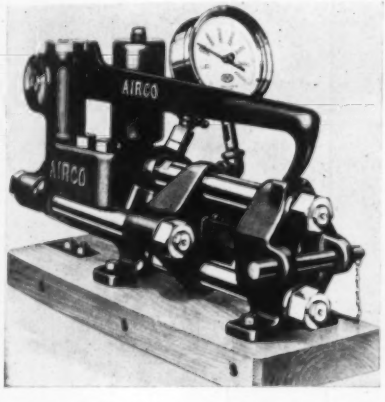
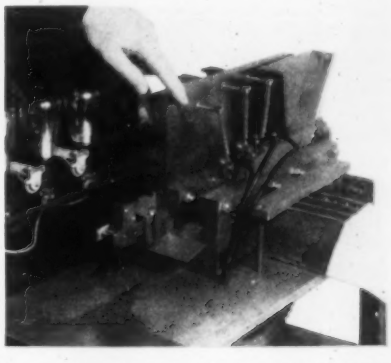


ample for nearly all materials. Operation requires little effort. Readings are accurate to ±2%. For bend test, machine is provided with an anvil which fits into movable head and bends specimen against a pair of supports set 3" apart and cast integral with the body. Easy portability is a feature: solid hardwood base on which machine is mounted forms part of packing case. Sides and top of case are assembled with screws. A few minutes with a screw-driver frees machine for use or packs it for shipment. A separate box contains the gage, carefully packed.

Diameter Model of Automatic Inspector

Electronic Inspection Laboratories

THIS new addition to the maker's line of "Electronic Gauging Machines" has been developed for the single purpose of rapidly inspecting diameters of cylindrical parts fed into its hopper. The 3-chute model illustrated classifies parts into three sizes within the limits of tolerance, in addition to ejecting "overs" and "unders." The usual size classification is by 0.00001" but the ultimate gaging head sensitivity is better than a millionth of an inch. No skill is required for setting up, however, since the machine acts solely as a comparator with a standard. Bridge construction compensates for changes in the temperature of the gaging head, and the only temperature variation to be adjusted for is that of the micrometer spindles (which, however, is negligible when it does not exceed 20°F. Feed is positive and non-clogging, by reason of synchronized mechanism attached to a stacked hopper. All gaging parts are of tungsten carbide or stellite and all moving gaging bearings are V agate. *Operation:* Pieces to

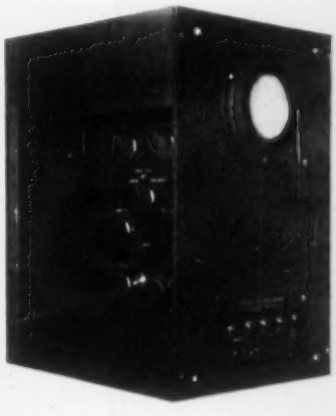


be measured are stacked in the V hopper over the feed roll. An 80-tooth positioning gear advances them consecutively on to the stellite anvils where they are contacted approximately in the middle by a carboloy-tipped spindle. This spindle is connected to an electronic relay which actuates an air valve blowing off the rejects. Similarly, the accepted pieces are sorted by size and delivered into corresponding chutes.

Industrial Cathode Ray Oscilloscope

Ralph R. Batcher

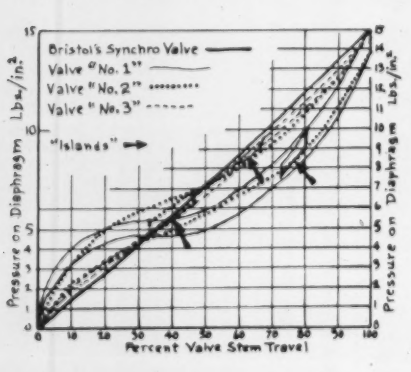
REFINEMENTS in design of cathode ray tubes and associated equipment have yielded new solutions of industrial testing problems. The modern oscilloscope now surpasses even voltmeters and ammeters in accident-proof operation. Its deflection system cannot be overloaded by mistaken connections. For many tests based on phenomena related to line frequency (such as 60 cycles) the auxiliary timing axis control equipment is much simplified. Examples: tests on condensers and cables, steel hardness testing by magnetic methods, machine vibration, checks on electromagnets, permanent magnets and transformers. Other auxiliaries make possible the rapid and convenient analysis of torsional and shearing stresses in shafting and rods, acceleration rates, engine indicator diagrams, and other measurements involving momentary variations in pressure, voltage, phase, relative displacements, etc. Designed especially for such applications, a cathode ray oscillograph has been made available, requiring a bare minimum of technical skill for operation: The few controls necessary for refocusing and for changing time base characteristics are reached by a side door, as illustrated, and the frequently-used ON switch and deflection system terminals are located in front for convenience. The tube is enclosed in a magnetic shield which, in conjunction with its location remote from any magnetic elements of the circuit, insures freedom from false deflection which produces distortion. The 16" x 10" x 12" cabinet has room for auxiliary equipment which may be required for certain tests. The tube and associated circuits are all operated from the a.-c. lines.



"Synchro" Control Valve

The Bristol Co.

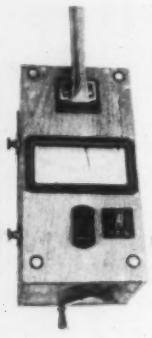
INSTANTANEOUS change of valve position in response to change of pressure on diaphragm top, and smoothness in such response, are said to characterize this new control valve, which has been named "Synchro" because of these characteristics. In support of claim of consistent relation of valve position to pressure regardless of whether pressures are rising or falling, manufacturer has published four curves described as follows: "These curves were made by plotting pressures on diaphragm against valve stem travel. Three representative diaphragm valves were tested under the same conditions as Bristol's Synchro Valve. Tests were made on a specially constructed test apparatus which automatically drew the curves. In making these tests, pressure was gradually applied up to an intermediate point, then slightly reduced and after the reduction increased to a 15-lb. maximum. From the maximum, the pressure was gradually reduced to 0. The point of intermediate reduction shows up clearly in the 'islands' in cases of diaphragm tops 1, 2 and 3. In the Synchro Valve, when this intermediate reduction occurred the valve receded along the same line as on the increasing pressures. Similarly, during the period of pressure reduction from the maximum, the Synchro Valve returned on the same line which it made on the rising pressure. The three other diaphragm tops showed distinct rising and falling pressure lines." These features are said to be accomplished by correct design of the rubber diaphragm and top, precision measurements in the manufacture and assembly of the stem guides, accurate alignment and proper spring construction. Construction simplifies maintenance and servicing. Ample space is provided for renewing stem packing without disturbing the adjustments. Top may be renewed or spring replaced without changing setting of spring follower. Union and valve bodies of V-port or single seated construction are available.



"Megger" Capacity Meter

James G. Biddle Co.

DEVELOPED especially for industrial use by manufacturers of radio and other types of electrostatic condensers, and for miscellaneous capacity measurements in shop or laboratory, this new instrument is a portable, direct-reading, multi-range microfarad meter, which is said to include for the first time, in an instrument of this character, a self-contained source of test current. To make a test, simply connect the condenser or circuit, the electrostatic capacity of which is to be measured, to the terminals, turn the crank of the hand-generator and read the meter scale directly in microfarads. Since no outside source of current is necessary, the instrument may be used anywhere. It is similar in construction and appearance to the makers' "Megger" insulation and ground testers: wood case; self-contained including hand generator; portable; weighs between 20 and 25 lbs. *Principle.* The instrument is a direct-reading a.-c. moving coil ratiometer. The capacity to be measured is connected in series with one coil of the ratiometer and a suitable standard capacity, contained in the instrument, is placed in series with the other coil. When the test voltage is applied the deflection of the pointer is proportional to the ratio between the currents in the two coils, and therefore the scales can be calibrated directly in microfarads. A feature of the portable type instrument is a provision by which the accuracy is not impaired if there is a parallel leakage resistance of 10,000 ohms or more associated with the capacity under test. The ranges of the portable type shown are 0 to .3, 0 to 1, 0 to 3 and 0 to 10 microfarads. There is announced also a "Workshop Type," ranges 0 to .003 and 0 to .01 microfarad; for operation from 115-volt, 60-cycle supply; not compensated for parallel resistance.



Heavy-duty Rheostat

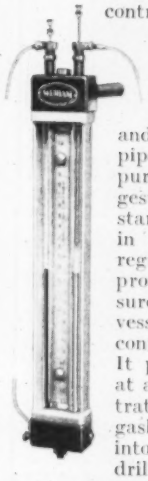
American Instrument Co.

DESIGNED especially for laboratory service, the new No. 1522-01 rheostat provides smooth control of current for operating heaters used in distillations where temperature control must be precise, also laboratory motors where speed control is required. A heavy roller contact provides positive contact without wear on winding; a heavy nichrome winding is said to eliminate danger of burning out when contact is near zero position. Dimensions, 6" x 6" x 5½"; 115 volts; 6.5 amp.; resistance 114 ohms.

Manometer-Regulator

The Meriam Co.

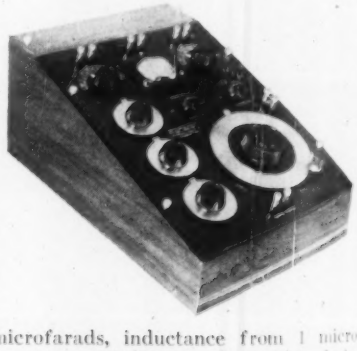
FITTED with automatic electric control features, this new instrument is said to be rugged, simple, accurate under severe service conditions, adaptable to direct or differential control uses for pumps, liquid levels in tanks and sprinkler systems, and for maintaining gas pressure and flow between close limits; or for starting and stopping the flow in two pipes alternately for special purposes. Other uses suggested are the automatic starting of a reserve pump in case of a failure of the regular unit to operate, the production of alternate pressure and vacuum in a closed vessel, or for electric remote control of steam valves, etc. It provides a visible reading at all times. In the type illustrated, two glass tubes are gasketed at their lower ends into an iron block which is drilled to provide the U-connection between them. Three terminals are provided—one on the block and the other two at the upper ends of the tubes. These latter terminals are connected to corrosion-resistant, adjustable tungsten wires which pass through Bakelite plugs in the upper ends of the tubes and which may be set so that either of them contacts with the mercury at the predetermined differential pressure or vacuum. The difference between the depths of the two upper contact points may be made as small as desired.



"650-A" Impedance Bridge

General Radio Co.

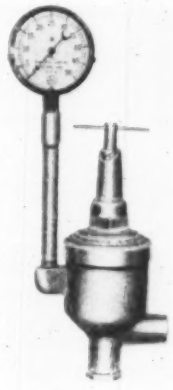
WHERE a considerable variety of impedance measurements are to be made, a bridge which is always set up and ready is an invaluable instrument. The Type 650 Bridge measures inductance, capacitance, resistance, dissipation factor and energy factor of coils and condensers over extremely wide ranges. Resistances can be measured from 1 milliohm to 1 megohm, capacitance from 1 micromicrofarad to 100 microfarads, inductance from 1 microhenry to 100 henrys, dissipation factor (R/X) from 0.02 to 1, energy factor (X/R) from 0.02 to 1,000. The bridge contains all standards for these measurements as well as the power source. Only telephones have to be connected externally. The bridge is direct reading for all measured entities, requiring no calculation of data.



Discharge-flow Regulator

The DeVilbiss Co.

DESIGNED particularly for use with circulating-system spray-painting equipment, the new Type HG Fluid Regulator assures constant fluid pressure at each spray gun; so that the gun farthest from the pumps is fed at the same fluid flow and pressure as the nearest. The "blow back" feature is included: If the valve is opened while the operator cleans his hose by blocking off the air at the nozzle, the air and paint ahead of it will be blown back through the regulator. The regulator screw, a removable key, locks the regulator at the desired pressure and eliminates tampering. Valve stem and valve seat are of hardened stainless steel, both ground to a positive seal. It is said that simplicity of construction and accurate machining insure efficient service and long life under severe usage. Available with 50-lb. pressure gage with 6" tube (as illustrated) or without gage or tube.



Condenser Analyzer

Tobe Deutschmann Corp.

IN spite of rapid development and changes in design of condensers, and especially of the introduction of the electrolytic condenser, it is said that up to now little attention was given to the design of an instrument that would help solve condenser problems. The Tobe Condenser Analyzer has been designed specifically as an aid to the solution of problems involving condensers and condenser testing. Paper, mica, and oil dielectric condensers are tested by the method of measuring the d.-c. resistance under an applied voltage. The resultant leakage current is indicated by means of a neon glow tube. Good condensers having a satisfactorily high resistance, as well as open, shorted, intermittently open and closed, and poor leaky condensers are said to be readily indicated. Especially noteworthy is the complete analysis the instrument affords electrolytic condensers. The instrument contains a built-in power supply operating on a 110-volt 60-cycle a.c. Voltages up to 700 volts d.c. are available for testing at the output terminals. The case is of metal, finished in black Damaskene wrinkle. Dimensions are 3¾" x 4½" x 7½".

Mercury-switch Type Indicating Controller

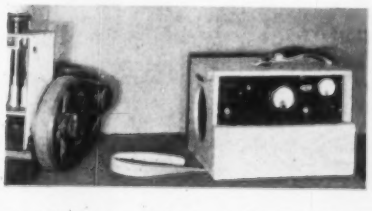
The Brown Instrument Co.

USE of mercury switches instead of open make-and-break contacts controlled by the pointer, is a feature of this new automatic control indicating thermometer. Every six seconds a motor-driven control table determines the location of the pointer in reference to the control setting, and tilts the mercury switch from one side to the other if the temperature has changed. Thus the measuring system is free to position itself, unhampered by the control mechanism. There is no distortion or restriction of pointer movement. Action is not dependent upon friction, as switch is positioned by the electric motor. Contacts are unaffected by vibration, as switch is mechanically locked in place until a different position is required. Corrosion and dirty contacts are eliminated, as switch is sealed in glass. Mercury switches have capacities up to 15 amps. at 110 volts (10 amps. at 220 volts), obviating need of external relays in most applications. Control mechanism is adaptable to one-, two-, or three-contact control (or signalling) systems. Measuring system and control mechanism are essentially identical with those of maker's temperature recorder-controllers. This type is said to have given excellent service where it is desired to measure temperature at distances up to 200 feet and at the same time control or signal. All models are furnished in 10" universal cases having all the features of the new Brown recorders (*Instruments*, January 1934, page 19). Models are available for control of pressure, liquid level, etc., as well as temperature.

"559-A" Noise Meter

General Radio Co.

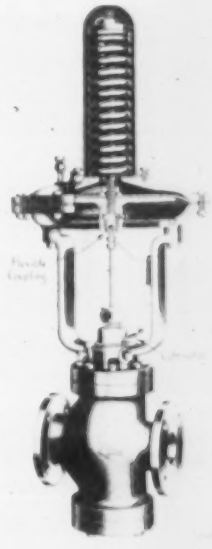
SIMPLE, rugged and entirely self-contained, this instrument is calibrated directly in decibels and makes it possible to measure accurately over a range extending from the rustling of paper to painfully loud noises. It, therefore, has already been adopted by manufacturers of home and office equipment. Picking up the noise through a hole in one end (see photograph) and requiring no expert manipulation (the only operating controls are an on-and-off switch and a range selector) it affords utmost convenience in use. Overall frequency characteristic is similar to response of human ear, but circuit allows filters of various characteristics to be inserted. External microphone may be connected. Dimensions, 16½" x 11" x 12¼" overall. Weight, 33 lbs. without battery—space for which is provided in cabinet.



"Stabilflo" Control Valve

The Foxboro Co.

EXPERIENCE has shown that the success of automatic control depends as much on the controlled valve as on the controller. The new Stabilflo Valve has been developed with the importance of its function clearly in mind, and is said to contain startling innovations in design and construction of the diaphragm motor and of the valve ports. Reversing usual position of diaphragm and spring is said to result in a valve that always gives an exact response to the slightest change demanded by the control instrument. Suspended construction of the Stabilflo diaphragm motor insures smooth valve action. The motor requires no guides, thereby eliminating a source of friction. Special flexible coupling between diaphragm motor and valve stem permits the stem to establish its normal alignment. Smoothness is enhanced further by a valve stem lubricator which minimizes stuffing-box friction. The lubricant protects and lubricates the packing and helps prevent leakage. To assure correct control throughout entire range of valve, the motor has been designed "with a power factor ample to give true control results equal to the theoretical valve characteristics." New valve port construction gives a flow rangeability of 50 to 1, said to be five times as much as present control valves and signifying that the Stabilflo valve has equal-percentage flow characteristics between 2 and 100% valve capacity. Valve and motor are ruggedly constructed. Open-throat yoke permits air to circulate freely and helps to protect diaphragm against excessive temperatures. Chrome-vanadium steel spring is enclosed in an air-tight pressed steel chamber which protects it from corrosive action. Each valve is equipped with a position index that shows position of valve plunger, and also shows at a glance whether the valve is an air-opening or air-closing type.



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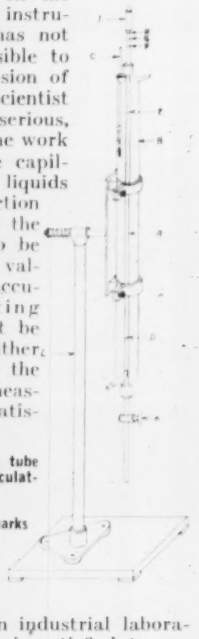
Cochius Viscosimeter with Precision Tube

Fish-Schurman Corp.

IN chemical laboratories glass viscosimeters are preferred because, due to their simplicity and chemical inertness, they possess obvious advantages over metal viscosimeters. In the manufacture of glass instruments, however, it has not heretofore been possible to obtain extreme precision of dimensions. To the scientist this drawback is not serious, for when doing routine work he can calibrate the capillaries with known liquids and calculate correction factors, but when the measurements are to be reduced to absolute values, dimensional inaccuracies and resulting turbulences cannot be tolerated, for neither the calibration nor the individual viscosity measurements would be satisfactorily accurate. In industrial laboratories, therefore, one is satisfied to use the efflux type, falling weight type or torsion type viscosimeters empirically calibrated by means of known liquids. Such viscosimeters only check against one another with genuine viscosimeter liquids, but if one investigates liquids which show viscosity anomalies they will not detect viscosity irregularities by reason of the differently dimensioned friction surfaces. These difficulties have now been overcome by the use of precision-bore K.P.G. glass tubes in the Cochius Absolute Viscosimeter. This instrument is of the bubble type which is the standard type in various industries. A vertical glass tube of standardized internal dimensions is filled with the liquid to be tested, and the time required for an air bubble to rise between two marks is measured. A jacket provides constant temperature. The accuracy of bubble type viscosimeters depends primarily upon that of the internal diameter of the glass tube, since the duration of the rise of the air bubble is so long that stop-watch errors are negligible. K.P.G. tubes having bores accurate to ±0.01 mm., a considerable advance has been made in viscosimetry.

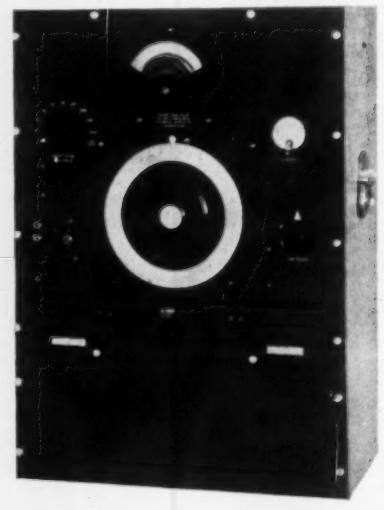


A—Precision-bore measuring tube
B—Constant-temperature circulating medium jacket
C—Thermometer
D, E, F, G, H—Reference marks
J—Sealing cap
K—Glass cock
L—Stand

Type 636-A Wave Analyzer

General Radio Co.

OF great importance in many branches of electrical engineering, the subject of wave analysis is of particular importance in connection with the new art of production and reproduction of speech and music, and with problems of telephone interference and power-line operation. Harmonic analyzers of many types have been developed, but it is said that the Type 636 Wave Analyzer presents a combination of simplicity of operation, sensitivity and accuracy which has not heretofore been commercially available. It makes use of a mechanical (piezo-electric crystal) filter in order to secure a sharpness of filtering greater than can ordinarily be obtained with electrical circuits. The incoming signal is heterodyned with a local oscillator to produce the filter frequency and the output of the filter will contact only a single frequency. The internal oscillator is adjusted to bring each frequency in the impressed wave in turn to the filter frequency, and the magnitude of each component frequency of the original wave is measured in turn. In practice this operation is simple. After preliminary adjustments of balancing detector have been made, operation of the instrument consists in the rotation

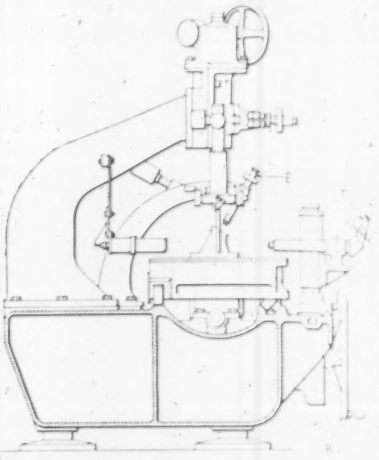


of a large dial calibrated in frequency. The voltmeter above the dial will register the magnitude of each frequency present in the component wave as that frequency passes under the dial indicator. Complicated analyses can be run through with great rapidity. Because of the use of a mechanical filter unusual discrimination between frequencies can be obtained. A frequency differing only 30 cycles from the one observed will be attenuated by 40 decibels at any frequency.

Thread Measuring Machine

R. Y. Ferner Co.

THIS recent development by the Société Genevoise d'Instruments de Physique, Geneva, permits of taking direct measurements on cylindrical and taper thread gages. For male gages, the maximum diameter is 2½" and measurements may be taken of the pitch diameter at any point of the thread; of the external diameter at any point; of the pitch parallel to the gage axis; and of the thread profile and angle. Female gages of diameters from 1¼ to 2½" can be measured for pitch diameter at any point; internal diameter; and pitch parallel to the axis of the gage. Male gages of diameters from 1¼ to 4" can be mounted between centers, when the handle is integral with the gage. Larger male gages and female gages are set on the table with the axis vertical. The displacements of the table are measured on a precision scale by means of an S.I.P. micrometric microscope *E*, reading to 0.0001 mm. (0.00005"). The column carries a second measuring microscope whereby the vertical displacements of the measuring anvils can be read to 0.001 mm. (0.00005") on a precision scale. The goniometric microscope *T* is adjustable vertically through a distance of 20 mm. (¾") and horizontally through 15 mm. (⅝"). The displacements are measured on divided drums reading to

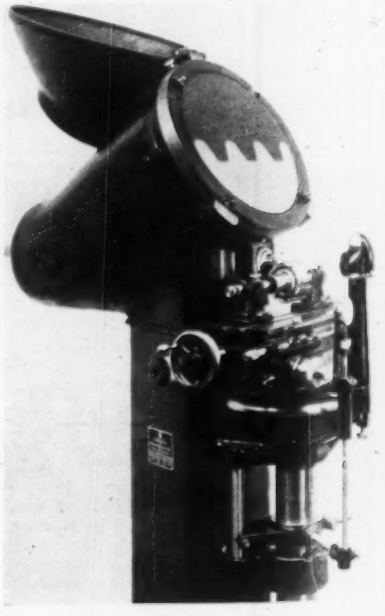


0.01 mm. (0.00005"). The microscope permits of taking angular readings to 1' and enables the thread profiles and angles of male gages to be checked. The two precision scales for the longitudinal movement of the table and the vertical movement of the measuring device are of special alloy, having the same coefficient of expansion as steel gages. Corrections for temperature variation are therefore unnecessary. The division of the scales is guaranteed to be accurate to ±0.0015 mm.

Pedestal Type Comparator and Measuring Machine

Jones & Lamson Machine Co.

FOR measuring and comparing objects by means of a magnified shadow, this optical projection machine has been designed to meet the requirements of toolroom, production or labora-



tory inspection. All operating mechanism is within reach of an operator sitting before the 14" diameter chart. Floor space required is 36" wide by 44" long. The supporting base has two large bearings for supporting and guiding the 3½" ram on which the table is mounted. Upper portion of ram is threaded and is encased in a 12" diam. ball thrust handwheel for vertical adjustment. Maximum vertical table travel is 6". Three styles of tables can be furnished:

A plain table without lateral adjustment.

Table with 4" lateral adjustment for measuring 4" of spacing or lead.

Table with 10" lateral adjustment for measuring 10" of spacing or lead.

All three styles can be swiveled 15° either side of center. Centers with standard center blocks will stage objects up to 5" diam., 12" long. A vertical measuring attachment can be supplied for measuring vertically up to 2". A vernier attachment permits measurement of angles in degrees and minutes. A standard 8"x10" photographic attachment can be supplied for photographing directly on sensitized paper, film, or plates, under ordinary shop lighting conditions. Provisions have been made for inspecting by reflection such objects as type faces, or contours having surfaces that cannot be projected. Machine can be equipped with universal stage for mounting production screws to measure form, lead and pitch diameter. The following lens systems can be supplied for projecting objects of various sizes:

Lens system	*Projected area*	*Magnification*
25 mm.	$\frac{8}{44}$"	200
38 mm.	$\frac{4}{44}$"	100
48 mm.	0.200"	62.5
46 mm.	$\frac{1}{5}$"	20
82 mm.	$\frac{3}{4}$"	12

Gear Analyzer

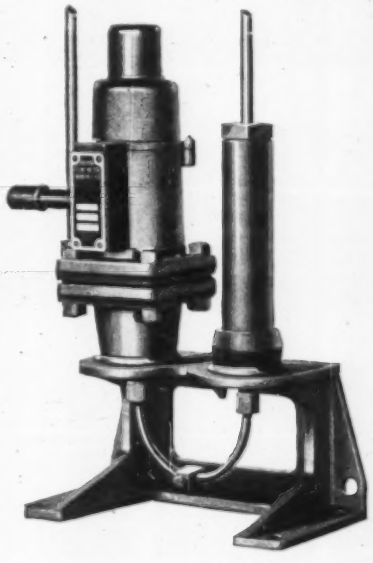
Michigan Tool Co.

RAPID checking of involute gears has been realized in the new Involute Checking Machine. No master forms or master base circle disks are required. Charting for comparison with other checking devices is readily accomplished. A sine bar is employed similar to those embodied on other Michigan Tool Co. inspection instruments. By use of two indicators and a reversible indicator finger, both sides of a gear tooth may be checked without dismounting, turning gear upside down or otherwise altering the set-up, thus making possible more consistent checking than could be obtained otherwise at reasonable labor cost. Constructed rigidly for lasting accuracy, the new machine has a capacity of 12" diam. by 12" length.

Electric Flow Meter Body

The Brown Instrument Co.

EASE of cleaning and of range-changing are said to be combined with ruggedness and simplicity in this new meter body for electric flow meters. Employment of inductance-bridge

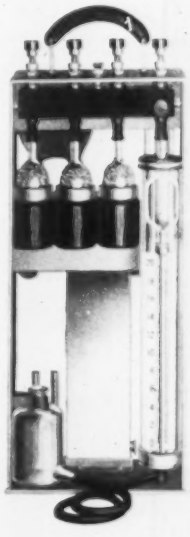


principle makes it possible to transmit electrically to remote indicating or recording instruments the position of the float which is free to move in the high-pressure chamber: no pressure-bearings, gears, links, chains or mercury contacts. High- and low-pressure legs are connected by heavy seamless steel U-tube attached by compression fittings and provided at its low point with a hard needle-point screw type of mercury drain. Mercury "blow-over" is prevented by oil-resisting resilient seals above and below the float. No welding or welded parts are used: construction permits working pressure of 2500 lbs./in.² (each body is factory-tested to 5000 lbs./in.²). Base is interchangeable for wall or floor mounting and made of malleable iron to stand shocks. All parts and fittings mounted on base are easily reached with a wrench. Entire body can be taken apart, cleaned, and reassembled in less than an hour, without removing piping, disturbing setting or re-calibrating meter. Range can be changed quickly without shutting down the line: nine interchangeable range tubes with corresponding charts for the recorder are available, each furnished with the right length of pipe, range tube support and gaskets all assembled as one unit. Change requires no pipe fitting, no vise and no special tools. External pulsation check is designed for precision adjustments with the meter body under 2500 lbs./in.² line pressure. The mercury drain may be opened and closed, carrying the pulsation check with it but not changing the setting

Portable Gas Analyzer

Ellison Draft Gage Co.

HEADER and seats are hard rubber, corrosion-proof. (A troublesome problem in analyzers had been solutions corroding metal header, seats and valves.)



Use of hard rubber was made possible by new type needle valve with swivel joint. Each end of header is provided with a hard rubber screw plug for cleaning header passage with a pipe cleaner. Another new feature is a needle valve system for the burette with two valves, having four operations same as a cock, requiring no grease, combining a corrosion-proof, leak-proof and greaseless header. Scale readings are visible at a distance of several feet. The analyzer is made in two scale ranges, 21% in 0.2 ml. subdivisions and 52.5% in 0.5 ml. subdivisions. The scales, with burette and jacket, are interchangeable. Absorption chamber is of annealed glass, and is filled with curled hard rubber. The chamber for the acid cuprous chloride solution is provided with copper for reducing the solution to a straw-yellow color. Solution container is of hard rubber and is filled and emptied through a nipple from the back of the analyzer without removing the container. For carrying the solutions, the nipples are closed with rubber caps. When in use, the caps are removed, leaving the CO_2 container open, the nipples for the O_2 and CO containers being sealed from the atmosphere with the air bag. Burette bottom is held in a packing cup with rubber gasket, finished with asbestos packing. Provision is made for carrying a complete testing set in carrying case, comprising gas sampling tube, pipe adapter, 2 flue gas thermometers, 2 thermometer holders, and Ellison portable draft gage set. Surfaces along burette jacket and case at the right serve as a guide for the leveling bottle over the full length of the scale. The new needle valve has been tested up to 100,000 operations without appreciable signs of wear. Header and fittings being of hard rubber, for stationary use where weight is not objectionable, mercury can be used for the leveling liquid, requiring no aspirating bulb. Air bag for sealing O_2 and CO solution reservoirs from atmosphere is of black pure gum rubber, provided with two nipple connections, one bag serving two containers. Gas sampling tube, $\frac{5}{16}$" x 17", is screwed into a brass bushing in bottom of case. Gas pipe adapter, threaded to take either ¼" or ½" iron pipe, is used for deeper insertions than the length of the sampling tube permits. Thermometer furnished is best grade "Taylor," etched stem, 16" long, 100 to 950°F. in 5° divisions, 3" immersion. Both the one-chamber and the three-chamber analyzers come with complete equipment.

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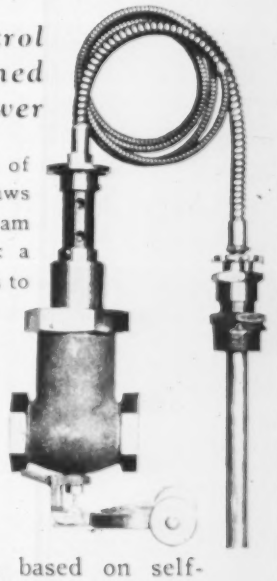

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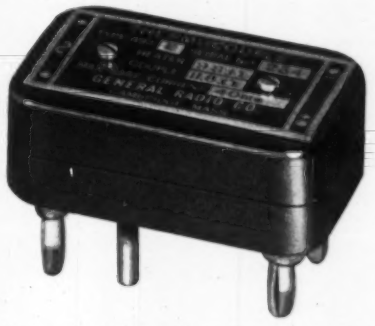

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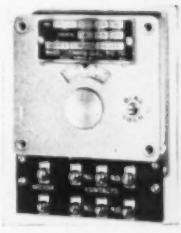

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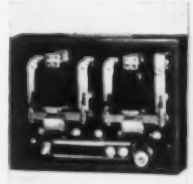

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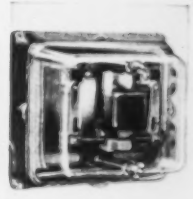

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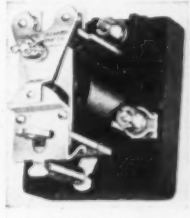

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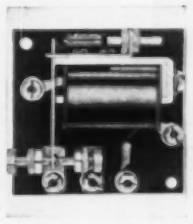

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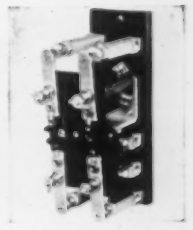

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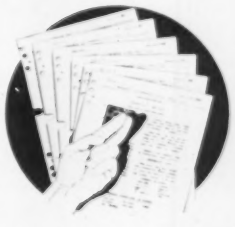

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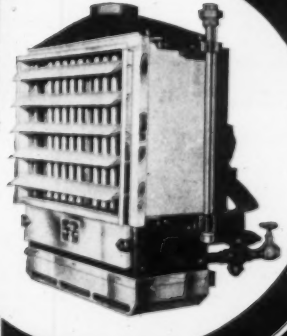

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